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THE PHILOSOPHICAL AND PRACTICAL ASPECTS OF THE ECONOMICS OF CANCER CONTROL

JANEWAY LECTURE, 1941*

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UP TO this time each Janeway lecturer has considered some phase of radioactivity, thus honoring immortal attributes of Henry Harrington Janeway and coincidentally discharging a responsibility to this Society which measures the progress of radiation therapy. Today, however, with the world falling about us, it is scarcely necessary to find an excuse for divergence from preceding, traditional subjects.

Attempt will be made to step out upon broader bases than this highly specialized group requires. The title is so all inclusive that there need be no limitations. The intimacies of any special group studying particular divisions of the art and science of medicine fade into mere decorations upon a grand canvas against conflicting motifs of world chaos, human suffering and social tragedy.

One can be quite sure that the spirit of Janeway would forgive the displacement of emphasis upon radioactivity for the larger problems whereby scientific progress itself may be dislocated, halted, and even buried. Civilizations have been buried before but never before has autocratic power or political favor been opposed by the scientific spirit that the world now enjoys. Science is too youthful to die without a titanic struggle. Philosophers and philosophies have come and gone. Science, with its measured facts of life and things, with its controlled, methodic surveys and experiments, is constantly building that force which in its constancy and devotion to stalwart truth may find answers to the social unrest and the cancerous world politics that disturb us today.

AMERICAN LEADERSHIP IN SCIENCE

Have we stopped to consider the demand that the present World War is making upon America for the preservation of science and the scientific spirit? We may not only have to step in to save the world for democratic freedom and all that this connotates but we are also rapidly becoming the last reservoir for harboring the scientific refugees from the universities of the old continent.

We have felt that America was a world leader in science. It is true that we have been more industrious in applied science and have been snatching at the flag of leadership in medicine and surgery until its continental origins are fairly frayed. Let us, however, look at the record. Have we not been guilty of arrogating to ourselves

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more than our full measure of the world's progress in surgery, public health, possibly cancer and probably many more fields? Of the six Nobel prizes of 1939, there were five to Europe and one to America. There is no doubt that we have been dependent upon European sources for many factors of our scientific culture. Now that these sources are dammed behind war fronts and many of them destroyed with their country's culture there is the necessity for America to assume the leadership.

When the sources of learning, science and culture are dried up by war, not only the professors and fellows are lost to progress but the great groups of students in their wakes are lost to the future. War not only grinds soldiers, citizens and even children in the dust but it creates a dust bowl that future generations must refertilize and cultivate before any scientific spirit and accomplishment can sprout again. Moreover, when frontiers are closed by war there is no longer that comradeship of scientists that provokes useful adventures through the exchange of ideas and of literature. The whole world would halt in what we hope is useful progress if the flame of science were not kept lit somewhere, somehow. Unfortunately, science and culture cannot bivouac for an intellectual rest. Science must be kept nourished by thoughts and ideas that have no place to develop amidst the terrors of warfare. We cannot establish a blackout for science for the duration and then expect it to flourish when the bombing is over. This is especially true in the total war that is now the world's fashion.

This matter of scientific leadership, or at least guardianship, during the struggle of all other nations on the face of the earth offers a great opportunity to America. We have gone a long way in harboring many brilliant minds from other countries. Moreover, with some questioning but no denial we have given refuge to many others who do not add to our intellectual wealth but merely disturb the fringe of science in the practice of medicine. We feel that there is a difference between these scampering refugees and those nobler exponents of the true scientific spirit who are detached from their home laboratories through accidents of birth or the destruction wrought by war. The latter are more constructive—and we still have hopes of Americanizing the former.

We may have to cultivate to produce leaders. There is the capacity and brilliancy latent within us. With no one to follow we must lead. With all other sources wiped out, we must carry on.

POPULATION TRENDS; EUTHANASIA; SOCIAL SECURITY

Among my early thoughts upon the philosophy and economics of cancer there arose consideration of the plight in which so-called civilized countries with aging populations find themselves. We easily agree that cancer is found more often among those over forty. Today there is an actual gross increase in those who reach this age and beyond. We must distinguish between the very aged ones of this group and those of late adult age who are still productive and of great value socially in bringing up the succeeding generation. The latter are the cultivators of youth and the custodians of the aged. They carry the load of life with its worry, its happiness and its taxes. The greatest curve of cancer deaths is in this important age group.

We need not worry too much about the old age group. Their tissues have stood the wear and tear of life's major struggle and they can carry through with their cancers far easier than the younger group. They respond to treatment more successfully. They may even survive with very little, if any, treatment. In such a senile state their cancers do not grow rapidly and very frequently provide an easy and convenient exitus from the years of alleged security, a security often present in name only.

I shall only mention the subject of euthanasia for fear that I might be accused of emphasizing this moot topic. Among the older practitioners of medicine who have been obliged to face lingering and futile

situations there is agreement upon its usefulness and comfort. No one, however, has yet devised a scheme for its application because it takes a supernatural judge, in competition with God, to agree on its verdict or impose its sentence.

It is much easier to dispose of these unpleasant aspects of cancer philosophy by agreeing with the Darwinian concept that the survival of the fittest is a natural law. One does not easily accept a Nietschian philosophy that would impose death upon those who have weathered the gale of life to old age.

Population trends and euthanasia are of more limited importance in cancer philosophy than in racial, geographical, political and martial spheres. They are almost outside of the domain of medicine. There are those who like to meddle with life and to them I gladly leave these topics. We are concerned with saving life. We are not legal executioners. We are not prepared to judge the living but to save them for living their own lives.

SOCIOPOLITICAL DISCUSSION

In various professional and political discussions about social improvement there is the recurring admonition that welfare services are getting too expensive. Private charities have gradually veered away from direct relief and have increased their spending for character-building and self-help programs. In spite of this improved program, they still rely upon an appeal that promises surcease from suffering and relief from want. At the same time government by a majority choice has assumed the food, shelter and clothing division of charity. Hence private charities, basing their appeal on relief that is now governmentally dispensed, find it increasingly difficult to secure volunteer funds for endowed scientific research. Moreover, at the very time that philanthropy is cutting its contributions, former generous endowments suffer the same short measure of return that savings and general investments do.

This actual scarcity of money for private philanthropic purposes, freely given in the past, is intensified by a changed attitude in both the donors and the recipients. Since the government borrows at low rates of interest, former donors are ready to agree and even insist that government carry the major burden of charity or what is now dignified as relief. On the other hand, among those forced to accept largesse, either private or public, what was gratitude is now a social demand and an indispensable right. Individual pride and responsibility have been displaced by fawning for favor. The pride that once supported the under-dog in his will to fight has been diluted. Has it been damaged beyond revival or rejuvenation? Dependence on governmental programs has been fostered in place of independence and self-reliance. Imagination, ambition, thrift and a host of such qualities that inspired both youth and adult to strive and grow and succeed are about to become punishable crimes or conspiracies against a benevolent government. It is almost possible to say that weakness and dependence are encouraged, strength and ability penalized.

The cancer problem is influenced by these trends. The denial of funds for independent research, educational programs and propaganda will hinder progress; to what extent we will never know. The transfer of cancer research and education to a governmental agency or institute is bound to influence the present favorable trends of the cancer problem tremendously. I am not attempting to minimize or even criticize the individuals who are intimately identified with this governmental program at present. These individuals are carrying with them their original enthusiasms and ambitions as well as the influence of their late teachers. It is absolutely and eternally impossible, however, to divorce politics from any program, bureau or board that is tax supported. Our apprehension is not for the immediate success of such institutions but for the years and generations ahead when the personality of those in charge of the whole and the parts has been warped by

politics, tinctured by indecision and diluted by smugness and favoritism.

Another objection to governmental control lies in the absorption of funds by overhead expenses for bureaucratic administration. This results in an economic weakening of the facilities and personnel for research and the dissemination of scientific facts. Further, prohibitive costs may follow governmental experiments in the distribution of consultations and treatments for cancer and other specialties. Under our present system of attempting to shorten the gap between knowledge and practice we are well aware of the economic difficulties encountered in the parallel extension of specialized medical service and general medical care.

There is no doubt that at this time we should give up any ideas of adequate sums from any private or public sources for huge centralized institutions for cancer treatment. The history of most institutional care of any categorical disease indicates that the institutions become the custodians rather than the healers of their clientele. Witness the insane, the tuberculous, the psychopathic, the epileptic colonies. One may add to these the all-inclusive Veterans' Facilities. Their clientele is not usually discharged as cured but graduated by death.

If we are going to show improvement in the cancer problem there must be an acceptance of some individual responsibility by the cancer patient himself as well as his physician. The shifting financial support of his care cannot eliminate his personal responsibility. Even though police power to force him to undergo professional care were added to financial help, there would be the necessity for personal responsibility. Sweden gave police power and complete financial support, including institutions and ample equipment, to her cancer problem. Nevertheless, her morbidity and mortality statistics have not inspired the rest of the world to copy her technique. Sweden's statistics upon the life career of cancers and her comparisons of techniques of treatment have been most valuable. Her program, however, did not bring to light early cancer for there has been the continued lament of procrastination in seeking diagnosis. This is a vital point. Sweden's police power was never directed toward periodic examinations but merely toward insuring the return of patients for treatment and observation. No government has yet promoted a compulsory health scheme to unearth early cases of cancer, hypertension, diabetes, pernicious anemia or heart disease by periodic examinations. The only diseases that public health measures have controlled to any marked degree are the infections and contagions. It is quite evident that by the time people reach late adult life, when the cancer problem assumes major importance, they are either too resistant or too irresponsible to agree to or accept periodic examinations. Goethe was probably right when he said that the weakness of democracy is that it has to wait for an enlightened public opinion. It would be interesting to know what a totalitarian government would do, if anything, to promote this responsibility.

A SURVEY OF PRESENT CANCER CONTROL PROGRAMS

Whatever methods of organization for cancer control are pursued, be they private, public, philanthropic or governmental, one must never overlook the fundamental fact that a majority of the people are not eager to accept new facts, no matter how intelligent or worthy the source. On the other hand, it is true that whatever progress is made in cancer control or any other medical program depends upon the acceptance and the pursuit of the new idea by the family doctors, who compose the majority of the medical profession. Specialization is limited to 17 per cent of the American medical profession. Specialists may provide medical facts but it is the 83 per cent of general practitioners who must interpret and apply these facts to the general public.

Up to the present time, most organized methods for cancer control have been confined to institutions and hospitals within

metropolitan areas. There are a few isolated institutions that enjoy a rural location but they are usually the result of conspiring rather than inspiring political maneuvers within a state. The average state legislature always has a conflict between a majority of rural legislators and a minority of metropolitanites, both seeking to plant political plums. A geographical center is rarely a population center.

The American College of Surgeons has promoted a meritorious program to establish Tumor Clinics in existing institutions that possess adequate facilities and an ambitious staff. The most successful are in large hospitals with well-patronized outpatient departments. There is no discounting the merit and the service rendered by these Tumor Clinics. The brilliancy of their success usually depends upon the ambition and drive of an individual, plus the cooperative spirit engendered in the staff. Rarely does it excel the level of the given institution. Unfortunately these Tumor Clinics in metropolitan hospitals are burdened with a good deal of late cancer that cannot enjoy ablative or curative surgery but is forced to undergo palliative irradiation or physiological surgery. The statistical increase in early cancer seen is exceedingly slow in spite of the build-up through professional and lay channels. While the organization and the efficiency of the Tumor Clinic seem ideal, we still find that any increase in its statisticaal merit depends upon the average doctor of the community more than the professional capacity of the Tumor Clinic.

The statistics of the few hospitals limiting their work to cancer in this country are almost identical with those of the Tumor Clinics as far as the admissions of early, curable cancer are concerned. While the research departments and treatment facilities of these Cancer Hospitals provide the facts of progress that point the way to the future, they still lack the practical approach to the early cancer victim. The intensive study of cancer that these institutions provide is so necessary for progress and so stimulating to all other methods of cancer control that one hopes their programs will continue to obtain philanthropic support. Their future depends so immeasurably upon their autonomous direction and staff organization that any invasion of their rights and privileges for free scientific thinking and experimentation would be disastrous.

There are several state programs for cancer control. The Massachusetts program was forced upon a procrastinating profession and it is surprising to find how much professional support it has achieved. It combines state hospitals in rural areas and numerous Tumor Clinics in metropolitan centers. It is interesting to note that, as the rural tumor clinics have developed, the state hospitals have become burdened with late rather than early cancer cases. This development is in accordance with my earlier statement that large institutions become the custodians of terminal cases.

Some states, with Connecticut leading the way, have organized Tumor Clinics under the auspices of county medical societies. State funds are limited and confined mainly to clerical assistance. These programs always compromise private enterprise. Patients are usually from the indigent groups and there is rarely much professional enthusiasm. Such programs are prone to result in an increase of state medicine because the director has already compromised his private practice with that of a state-subsidized project. Any program of a state medical society will stand or fall by the measure of professional enthusiasm that the director can arouse. If this enthusiasm wanes, he then conspires to introduce more state-supported measures in order to justify his job. It would be better for state medical societies to confine their programs to educational efforts among their own ranks and to lend their Voice of Experience to the Women's Field Army.

DECENTRALIZED CANCER CONFERENCES

Throughout all cancer education and propaganda there is the constant advice

that early cancer can be cured. The second admonition is to seek a medical examination. There must be the suspicion of cancer by a patient, plus the examination, plus adequate treatment to effect the consummation of the original advice. There would be less necessity to develop such suspicions in an informed laity if there were frequent periodic examinations, examinations conducted with much cancer-consciousness on the part of the physician. The element of suspicion, however, in both the patient and the physician is of tremendous importance. One of my worthy friends insists that "a condition unsuspected is rarely diagnosed." There must be a high index of cancer-consciousness.

After the suspicion of cancer has been aroused in either the patient or physician or both, it is necessary to confirm or deny it. If the physician is capable of establishing the diagnosis and completing the treatment properly, there is no need for further search. If this simple solution is not possible, then there should be some comparatively easy process by which contact can be established with consultation and adequate treatment, a contact easily available in metropolitan centers but difficult in rural sectors. I think I have found such a process, one different from institutional tumor clinics, state or governmental hospitals. It consists simply of bringing the metropolitan specialist and his equipment within easy range of patients in sparsely populated districts by periodic clinics held at strategic points. Some inconvenience and effort are imposed upon the consultant by this plan but reduced for the patient in the same proportion. It reduces immeasurably the troubles of the family physician.

Not for one moment is any disparagement or criticism of institutional clinics or hospital tumor clinics in urban centers intended. These are worthy. They have been successful and rightfully so. My ambition, however, has been to make it so easy, so simple for a suspicious patient or a suspicious physician, no matter what his location, to contact consultation that much procrastination and uncertainty are avoided.

This simple process brings the consultant to the patients instead of the patients to the cloistered metropolitan consultant. It is far simpler to move one consultant to ten patients than to ask ten physicians to argue ten patients into seeking one consultant at a distance. At the same time the local hospital and family physician are glorified, encouraged and expanded.

This proposal to make specialists function in reverse is decentralization with a vengeance. It is contrary to the methods in medical education that have served to create large medical schools and urban hospitals in the United States during the last fifty years. Now it is true that the advances in medical technique and research produced by these institutions are of fundamental value—but the newly graduated physician who could take these new facts to the towns and population centers in the counties usually prefers to remain in the city. Unfortunately even the country boy has been so well educated that he does not care to go back home. His sights have been raised. This cultural lag between research, new facts, new methods and clinical statistics and their absorption and application by general practitioners throughout the country has been shortened by the medical societies of county and state, by clinical conferences and by the tremendous medical literature of book and journal. Moreover, the manufacturer and his detail emissaries have merited some just praise in putting accordian pleats in the cultural lag.

This decentralization of specialists, while of inestimable value for early cancerous patients, has values for cardiology, tuberculosis, dermatology, psychiatry, neurology and orthopedics. One can conceive of specialty teams with definite itineraries. Here is a practical and simple method of distributing specialized medical services and at the same time developing the personnel, the physical equipment and more especially the prestige of smaller hospitals and clinics.

While this program has been developed

through private initiative, there is every reason to believe that it could have merit as a state government project, similar to those instituted in Massachusetts and Georgia. State projects, however, lack the enthusiasm and personality of private enterprise.

ORIGIN OF CANCER CONFERENCES

The idea of starting a cancer conference came over ten years ago when it was noted early in the depression that there was a distinct drop in the number of referred cases. One group of patients had come from towns along highways between Kansas City and northwestern Arkansas and northeastern Oklahoma. A trip to survey the situation was made. This covered nine counties in Kansas, six in Missouri, three in Arkansas and three in Oklahoma. All of these counties are grouped around Pittsburg, Kansas, 135 miles south of Kansas City. Within this area there are 500 physicians with access to completely staffed hospitals in seven large towns. While making the survey the idea of establishing a cancer conference in this territory was discussed with the physicians. It was disclosed that the overhead cost of ten patients going 135 miles or more for consultation could easily compensate for a day's time of a radiologist who could bring both consultation and the radium element needed for the treatment of a majority of the cases.

Out of this trip grew the first conference. It was located at Pittsburg, Kansas, where there was a group clinic, good space, laboratories for routine and roentgen examinations, excellent surgical, medical and other specialty consultation. The success of this adventure was immediate and so other locations were sought. Approved hospitalization and good surgical consultation to which oncologic consultation and radiation therapy could be added were the basic factors considered. Within five years six other conferences were established and not one has been discontinued. Two of the hospitals have installed high voltage roentgen therapy equipment because of the demand developed. A radiologist was added to one hospital and to the other a radiologist from a nearby larger city comes regularly.

ITEMS OF ORGANIZATION

Since one radiologist has found it pleasant and profitable to carry on with seven cancer conferences each month, others may be interested in this type of professional contact. For their consideration I will therefore enumerate briefly the items of organization.

Timing. I have found it convenient to visit each center upon a particular date each month, such as the 12th or 14th, rather than a particular day of the week so as to impress that date upon both patients and physicians. Conferences are not necessary more often since cancer is seldom an emergency, especially early lesions. The only emergency is a late complication. Placing all the conferences within one week leaves three weeks each month for regular practice at home. Moreover, strategic locations do not necessarily demand a whole day away from the home office.

Desirable Factors at the Location of the Conference. Surgical and medical consultation as well as equipment for roentgenographic examination are necessary. Pathological consultation is not essential since biopsy specimens can be transported. Roentgen therapy must be available. If the following equipment is not indigenous to the conference headquarters it may be carried easily by the consultant: limited electroscopic equipment, biopsy instruments, clinical camera for record, report and propaganda.

Physical Factors Supplied by the Consultant. Radium element and radon are not usually in the possession of the local community hospitals. Enough must be carried to provide treatment for superficial cases, those of mouth, lip and cervix. The radium element used in surface applicators in the morning becomes available for insertion and cavity cases in the afternoon.

Directorship. The radiologist is in the most favorable position to supply the great-

est number of items lacking in the local scene. He has the radium and expert roentgen knowledge. He has both general and special knowledge in oncology. He is less likely to disturb the local surgical field. In consultation with the local roentgenologist he is able to fortify the technical requirements of roentgen therapy.

Clerical Assistance. It is advantageous for the director to have his own clerical assistant to attend to reception and financial arrangements and other such details so that he can give his entire attention to the practice of medicine. The record clerk of a local hospital can complete the usual case record demands.

Sponsorship. Under private initiative the conferences may be sponsored under such auspices as: local group clinics with large followings, either professional or personal; county medical societies; local hospital staff; an individual physician with a large personal practice.

1. Local County Society. While this provides an excellent professional background it is without much personality except as the director supplies this item. There is no particular responsibility on the part of even the committee of the local society other than getting out the notices on time. This generally becomes just another function of the secretary's secretary. The spirit of cooperation is more difficult to inspire under such sponsorship.

2. Individual Physician's Office. It may be difficult for urban physicians to conceive of one physician becoming such a dominant character in a whole county of 400 square miles that the practice of medicine revolves about him. There are many such situations in the western prairie states. Within one day along important and rapid highways one consultant can make at least three or four advantageous stops to see groups of cancer patients in various doctors' offices.

3. Local Hospital Staffs. Many counties with one hospital care for the patients of all members of a county society. Such hospitals afford better auspices than the same county's medical society because there is an accepted responsibility that is rewarded by prestige and patronage.

4. Local Group Clinics. (*a*) Such a clinic with a large consulting following offers the best location. A spirit of cooperation is the basis of successful group practice and it is easy to fuse a cancer conference with a going organization. Both projects bring mutual support to each other. This method of sponsorship has proved to be the best. (*b*) In a clinic with a large personal following the success of an added cancer conference depends upon the extent of that following. The cancer conference adds to the prestige of such a clinic because it aids in building a more complete service.

SUMMARY ON CANCER CONFERENCES

This program of cancer conferences demands no expenditure of capital funds, either private or governmental, for buildings or institutes. Each locality already possesses the hospitalization requirements, the surgical personnel and, in fact, everything except the radium and the direction and consultation of a radiologist.

As the conferences have developed, my figures indicate that approximately one-third of the cases seen require some radiation therapy, one-third require surgery and one-third have either a cancer too advanced for help or some medical problem other than cancer. Each group has its own importance. Those requiring surgery pay directly to the cooperating surgeon fees comparable to the radiologist's. There are practically no fees to the last group except the usual small consultation charge, which may cover biopsy, roentgen examination and laboratory costs as well.

The main factors in the continued success of the clinics seem to be: the elimination of overhead travel costs; keeping the patient at home; fortifying and glorifying the local physician; and holding down the costs for indigents. Not a single one of these seven conferences has been stopped for any reason—and they have been continued for from four to ten years. They do impose some sacrifice on the consulting

radiologist through the regularity and responsibility assumed. He must be in attendance at each conference each month. Neither physicians nor patients will cooperate with indifference or negligence.

It seems that one week out of each month is enough for one consulting radiologist. Therefore, the same radium and the same portable equipment could be used by three other consulting radiologists each month. Four times the territory could be covered with the same capital costs of equipment and radium.

PERIODIC EXAMINATIONS

The question of timing or spacing periodic examinations enters into this cancer problem. Several years ago there was much stress upon the matter of such examinations. The benefits of periodic examinations for the recognition of actual or impending disease can be guaranteed. Whether or not they can be completed by the average run of physicians without specific training is questionable. Since they have never been popularized the question of professional capacity has not been tested.

There is only one physical survey of our population that is almost universal. That is the survey made when the child enters school, usually at five years of age. In sporadic spots there are yearly physical surveys of school children. The sifting of adolescents in high school for tuberculosis has enjoyed attention in some cities. That small portion of the growing population which enters college has enjoyed considerable and widespread attention in health surveys and competent examinations by physicians. Beyond this age there have been no surveys or periodic examinations imposed by law, custom or choice, except by the Draft. The current NYA surveys do not affect the cancer problem.

One can think of several spots that mark the spacing of a lifetime where a physical survey might be imposed and accepted. Many states have required certain items of physical well-being as a requisite for a marriage license. We have popularized the prenatal and postnatal examinations of mothers. Life insurance examinations reach only a selected few, and probably those most in need of a periodic examination avoid this voluntary test. I would propose that every voter be required to show records of a current physical examination at each registration, every four years at least. Every recipient of government aid, every applicant for blind pensions, family aid, and, more pertinently for the cancer problem, everyone who receives old age insurance could be required to undergo a thorough periodic examination. We must find some hook in the time and space of adult life upon which to hang a physical survey at intervals. An enthusiasm for such examinations will be hard to develop. There must be something that the adult must miss or be deprived of in order to establish the periodicity of examinations.

Coincident with the problem of prolonging life is that of making the added years productive. We have put much stress upon the increase of the life span without any recognition of the superimposed problem of protecting those in the later year groups. With our attention focused upon the single problem of longevity we have literally forced many individuals into years of life that are insecure. Can we justly boast of longevity as a social gain if it only prolongs and penalizes senility? For example, no one questions that we have added to the cancer problem by the increased numbers in ages beyond forty.

The medical profession and the engineers of public health measures may be allowed to absorb credit for longer years of life but they have avoided the parallel responsibility of maintaining this aging group in good health and security. Business and industry have not found any method of prolonging the activity of the aged. Politicians, it is true, have attempted to take over this responsibility but they can never find an answer other than the imposition of greater financial burdens upon those within the middle age groups who are still creative and productive. Whether the limited years of

adult productive earning can always carry the double load of longer years to youth and longer years to old age may become a critical problem. Inasmuch as science has succeeded in creating this large problem of old age, it must now apply itself to helping to solve its accompanying difficulties.

In the last analysis, however, science will not be able to achieve any solution unless the individual and the state cooperate. A Nazi technique might force a solution upon a people but it would be too cruel, too enslaving and too destructive to our conceptions of human rights. Also, it is doubtful if a New Deal technique in government can offer an adequate answer to the problem. The applications of the New Deal ideas have served to destroy initiative and responsibility in the individual who is down and out, forgotten, hungry or diseased. Favors that demand fawning sap the ability of the individual to work out his own destiny. The individual himself who, looking toward longevity, voluntarily seeks immunization and protection and the state that forces such measures upon its people must balance the responsibilities that longevity imposes.

CANCER OF THE NASAL CAVITY*†

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CANCER of the nasal cavity, compared to other malignant growths of the head and neck, is a relatively infrequent disease. Only an occasional article dealing with this subject is found in the literature, and many authors combine these tumors with somewhat similar lesions arising in the paranasal sinuses. The present report is based upon a series of 65 cases of malignant tumors of the nasal cavity referred for treatment to the Head and Neck Clinic at the Memorial Hospital over a period of thirteen years, 1928 to 1940, inclusive.

Definition. The term "cancer of the nasal cavity" designates growths arising in that portion of the nasal passage which lies between the anterior naris (nostril) in front and the posterior naris (choana) behind and is bounded by the septum, the lateral wall and the floor of the nasal fossa. The nasal cavity is sometimes erroneously designated as the naris. Anatomically, the anterior naris is the opening into the nasal cavity and not the cavity itself. The nasal cavity proper does not include the nasopharynx nor the accessory sinuses. Therefore, maxillo-ethmoidal tumors and epitheliomas of the nasopharynx should not be classified with neoplasms arising in the nasal cavity.

ANATOMY OF THE NASAL CAVITY

The nasal cavity or fossa is roughly pyramidal in shape, its apex lying in the superior meatus near the opening of the duct from the sphenoid sinus. The nasal septum divides the nasal cavity into a right and a left compartment extending from the nostrils (anterior nares) in front to the choanae (posterior nares) behind, at which point the air passages open into the nasal portion of the pharynx (Fig. 1). Contained within each cavity are the superior, middle and inferior turbinates and their corresponding meati. In the superior meatus anteriorly are the openings of most of the posterior ethmoid cells, and in the sphenoethmoidal recess is the entrance to the sphenoid sinus. The orifices of the frontal and maxillary sinuses and of the anterior

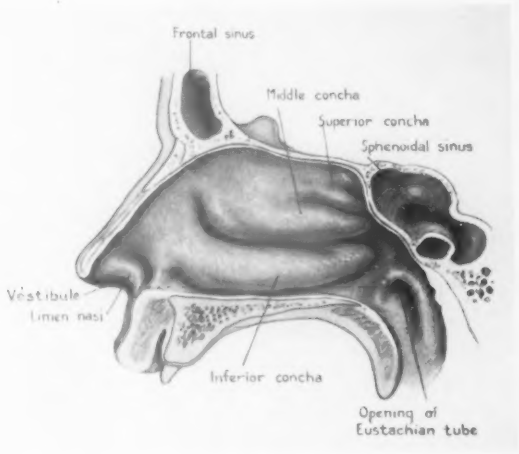

FIG. 1. Anatomy of the nasal cavity.

and middle ethmoid cells are contained within the middle meatus. In the inferior meatus lies the nasal ostium of the nasolacrimal duct.

The anterior portion of the nasal cavity (the vestibule‡) is lined with epidermis and in its lower portion there are hairs and sebaceous glands. The upper portion is smooth and is limited above and posteriorly by a slightly arched prominence, the limen nasi, beyond which lies the nasal cavity proper, lined with mucous membrane.

‡ There is much indecisiveness among authors about the correct use of the terms "anterior naris," "nostril" and "vestibule." It would seem best to use the first two terms interchangeably, but "vestibule" should apply only to the expanded forward portion of the nasal cavity proper.

* From the Head and Neck Service of Memorial Hospital.

† Preliminary report on this subject was read before the American Radium Society, St. Louis, Mo., May 15–16, 1939.

Each nasal cavity above and behind the vestibule is divided into a superior or olfactory portion and an inferior or respiratory portion. The olfactory region is a narrow slit-like space; it is bounded laterally by the superior nasal concha and mesially by the corresponding portion of the nasal septum. The respiratory region includes the remainder of the cavity.

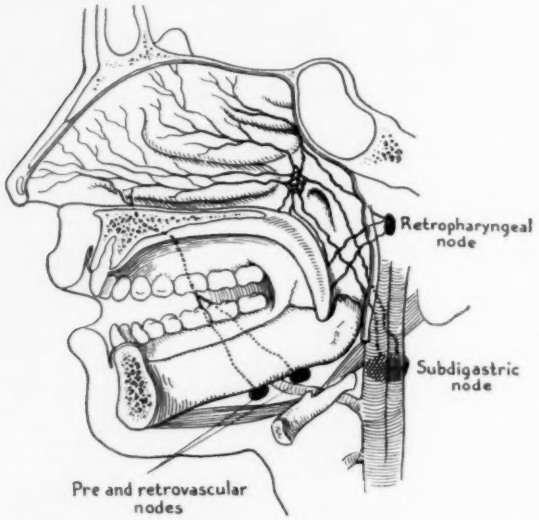

FIG. 2. Lymphatic system of the nasal cavity. The lymph from the anterior portion of the respiratory region of the nasal cavity passes downward and forward to reach the anterior facial vein and with it the submaxillary nodes, particularly the prevascular node. Drainage from the posterior portion runs backward and outward beneath the superior mucosa of the soft palate toward the pharyngeal orifice of the eustachian tube, at which point there is a plexus of lymphatics from the nasal cavity and the soft palate. Lateral collecting trunks pass outward, downward and backward across the posterior surfaces of the stylohyoid, styloglossus and digastric muscles, either in front of or behind the external carotid artery, and terminate in the subdigastric node. Posterior collecting trunks diverge from the deep surface of the levator veli palatini to proceed beneath the mucosa as far as the lateral angle of the pharynx, and enter eventually into a lateral retropharyngeal node.

The nasal mucous membrane is continuous with that lining the paranasal sinuses, the nasolacrimal ducts and the nasopharynx. In the respiratory region the mucous membrane is composed of columnar ciliated epithelium interspersed with goblet or mucin cells. Many acinous glands, secreting a watery fluid, are embedded in it and are especially large in the posterior halves of the nasal cavities. This mucous membrane is called the schneiderian membrane.

ANATOMY OF THE LYMPHATIC DRAINAGE OF THE NASAL CAVITY

The lymphatics of the vestibule of the nose unite anteriorly with those of the skin and subcutaneous tissues of the face. However, the lymph of the nasal cavity proper flows posteriorly toward the choanae. Rouvière[6] distinguishes two separate lymphatic regions of the nasal cavity, an olfactory and a respiratory. The first comprises the parts of the medial and lateral walls of the nasal fossae situated above a horizontal plane tangential to the inferior border of the superior conchae. The remainder of the nasal cavity below this imaginary plane is designated as the respiratory region. The lymph channels from the olfactory region pass directly across the cribriform plate of the ethmoid bone to unite eventually with the lymphatics of the subarachnoid space. The lymphatics of the respiratory region drain both anteriorly and posteriorly (Fig. 2).

ETIOLOGY

General Incidence. In the Head and Neck Clinic at the Memorial Hospital there is approximately 1 case of cancer of the nasal cavity in every 150 patients admitted to the service for cancer of the upper respiratory and alimentary tracts. Over a period of thirteen years, 1928 to 1940, inclusive, 65 patients were treated for malignant tumors arising within the nasal cavity.

Age and Sex Incidence. Im the present series of malignant tumors of the nasal cavity, there were 41 male and 24 female patients. The average age was fifty-five years, with the greatest number of cases falling in the sixth decade. The youngest patient was a girl of five, the oldest a woman of eighty-four.

Position of the Lesion. The tumor was found in the right nasal cavity in 25 cases of the present series and in the left in 31

cases. The lesion extended to both sides in 4 patients. Two lesions arose from the floor of the nose and 1 from the septum. In 12 patients, the tumor originated in the middle turbinate, in 6 in the inferior turbinate. In 2 instances the site of origin could not be determined.

Causative Factors. From the patients' histories no definite contributory factors could be determined. Smoking apparently played no part. No patient reported more than the usual number of respiratory infections common among the general population. There was, however, a history of chronic sinusitis in 5 cases, and 3 patients reported that nasal polyps had been removed repeatedly over a period of years. Geschickter[2] has suggested that tumors of the nasal cavity usually arise in the region of the turbinates, because it is from these areas that the nasal accessory sinuses develop embryologically. The conclusion then might be that infection in the sinuses would be a factor in the development of cancer of the nasal cavity. However, since chronic sinusitis and nasal polyps occur so frequently, it would seem likely that these conditions play only a minor part, if any, in the development of tumors of the nasal cavity. Rhinoscleroma of the nasal cavity may give rise to squamous carcinoma, as occurred in 2 cases of the present series.

HISTOPATHOLOGY

Only an occasional writer has attempted to classify tumors of the nasal cavity. Geschickter[2] has grouped the malignant epithelial tumors of the nasal and paranasal cavities according to their origin from the surface epithelium and appendages of the mucous membrane. Hautant, Monod and Klotz[3] divided the nasal cavity into three anatomic sections and designated as ethmoidal-orbital a group of tumors which arose in the superior layer. It would seem more reasonable to classify these tumors according to their histologic structure. Ewing,[1] a little over a decade ago, noted that a characteristic group of tumors arose from the schneiderian membrane, the cells being of undifferentiated polyhedral type. Since his publication, such tumors have been designated frequently as "schneiderian carcinoma." In the present series 10 tumors which were originally so classified have been reviewed recently by Dr. Fred W. Stewart, pathologist at the Memorial Hospital. On 8 his diagnosis has been epidermoid carcinoma; on the remaining 2 he has reported carcinoma with a question of mucous gland origin. In his opinion, schneiderian carcinoma is scarcely a definite histological entity. Clinically this seems to be the case also, since these tumors react no differently to irradiation than do the transitional cell carcinomas or Grades 3 and 4 of the epidermoid carcinomas.

Table I

HISTOLOGIC DISTRIBUTION OF 65 MALIGNANT TUMORS OF THE NASAL CAVITY AT THE MEMORIAL HOSPITAL

I. Epithelial tumors		47
Epidermoid carcinoma	34	
Transitional cell carcinoma	7	
Lympho-epithelioma	4	
Melanoma	2	
II. Glandular tumors		11
Adenocarcinoma	11	
III. Mesodermal tumors		7
Angiosarcoma	3	
Fibromyxosarcoma	1	
Spindle cell sarcoma	2	
Myxochondrosarcoma	1	
TOTAL		65

In Table 1 is given the histologic distribution of the lesions in the present series. Thirty-four tumors were diagnosed as epidermoid or squamous cell carcinoma, 2 of which developed on the basis of previously existing rhinoscleroma. Seven were classified as transitional cell epithelioma, 4 as lympho-epithelioma, 2 as melanoma. Eleven were reported as adenocarcinoma. The remaining 7 cases comprised a group of sarcomas in which there were 3 angiosarcomas, 1 fibromyxosarcoma, 2 spindle cell sarcomas unclassified, and 1 myxochondrosarcoma.

SYMPTOMS AND CLINICAL COURSE

The first symptom of cancer of the nasal cavity is usually obstruction to breathing (35 per cent of the present series). A sanguineous nasal discharge was the chief complaint in approximately 25 per cent of the patients, and both hemorrhage and obstruction were present in 14 per cent. Neither the patient nor the family physician attaches much significance to either of these symptoms since obstruction to breathing so often results from the formation of nasal polyps, while nosebleeds in themselves are not considered serious until they have become severe or have occurred at increasingly frequent intervals. Because of the usual slow rate of growth, the obstruction does not become complete for some months. Therefore, headache is not a prominent symptom until the nasal cavity is completely blocked by the disease so that the accessory nasal sinuses can no longer drain normally. Only one of the patients in the present series complained of headache on admission.

According to the histories of the patients in the present series, the average duration of symptoms before admission was eleven months. This average duration might not seem accurate, since a patient is inclined to pay little attention to the early symptoms of cancer of the nasal cavity, but it is interesting to note that among the successfully treated patients of this series the duration was the same as in those who died of disease.

Physical examination on admission in the present series usually revealed friable tumor tissue visible through the anterior nares. In 19 per cent of the patients the tumor had reached such size that external swelling could be noted beneath the inferior border of the nasal bone. In two-thirds of the cases it was impossible to determine the exact site of origin of the tumor because the lesion completely filled the air passage at the first examination. The appearance of tumors in this area is always complicated by infection since the nasal cavity normally contains many pathogenic bacteria. Infection increases the probability of bleeding when a biopsy specimen is removed, but such hemorrhage can be controlled by packing or external pressure. One patient in the present series was admitted first to another hospital because of severe hemorrhage which resulted from an attempt by her family physician to remove tissue which was obstructing the nasal passage.

The clinical course of malignant tumors of the nasal cavity is varied. The neoplasm usually grows slowly and causes pain or discomfort only by the pressure of the growth or by erosion of bone. With the increasing size of the tumor, the openings of the paranasal sinuses are eventually blocked, causing a pansinusitis. If no relief is obtained from this condition, the infection may extend into the cranial cavity. Many of the tumors extend directly into the orbital cavity by erosion of the lateral wall of the nose, as occurred in 50 per cent of the present series before admission to the Memorial Hospital. Extension of the disease into the orbit may cause exophthalmia or diplopia or both. Invasion through the ethmoids to the floor of the orbit was demonstrated by roentgen examination in 16 cases (25 per cent) of the present series on admission and in an additional 9 (14 per cent) at some time during the course of the disease.

In untreated cases or after unsuccessful treatment by irradiation and/or surgery, extension of the disease into the orbit results in limitation of ocular movement which may, in time, become complete. The expanding neoplastic disease in the nasal cavity causes increasing obstruction in the nasal passages, which prevents normal drainage from the accessory sinuses. Headaches increase in severity, and there is usually an elevation in temperature from the complicating infection (Fig. 3).

Metastases. Metastases from malignant tumors of the nasal cavity do not occur as frequently as would be expected from the degree of malignancy of the primary lesion. In this series of 65 patients, 8, or 12.2 per cent, were found to have metastases on

admission to the clinic, and 11, or 17 per cent, subsequently developed metastases, making a total of 19, or 29.2 per cent, at some time during the course of the disease. Of those presenting cervical metastatic involvement, the primary lesion was found in all cases to be histopathologically in the epidermoid group, and the region most frequently involved was the submaxillary (8, or 42 per cent of those which metastasized). In 2 cases the cervical nodes were involved bilaterally.

Distant metastases (to bone, brain, liver or lung) developed in 6 cases. The primary lesions in these cases were, histopathologically, epidermoid carcinoma in 5 instances and adenocarcinoma in one. It is interesting to note that the 2 cases of liver metastases were found on exploratory laparotomies performed in other hospitals. A biopsy of the liver in one case has been reviewed by Dr. Stewart and reported as epidermoid carcinoma. One patient developed metastases in the soft tissues of the upper arm from a primary anaplastic carcinoma in the nasal cavity.

In the autopsy records of the Memorial Hospital there are reports on 2 patients with cancer of the nasal cavity. One patient died of postoperative complications, and there was no evidence of metastases. The other, with squamous carcinoma, showed metastases to the lung and liver, although not to the regional lymph nodes, and direct extension of disease locally to the antrum and orbit. The number of cases is too small to permit any definite conclusions, but it would seem reasonable to expect a squamous carcinoma of the nasal cavity to metastasize to regional lymph nodes as do other squamous carcinomas of the intraoral regions.

Fig. 3. Far advanced cancer of the nasal cavity. The patient, aged twenty-one, after symptoms of nasal obstruction for ten months, was admitted to the Memorial Hospital. Biopsy showed anaplastic transitional cell carcinoma, Grade 4. Radiation therapy resulted in regression. Four months later the tumor recurred and was removed surgically. This procedure failed to control the disease. The accompanying photograph shows the disease filling the nasal cavity completely and encroaching upon the orbit.

Cause of Death. The main cause of death in cancer of the nasal cavity is uncontrolled or recurrent disease at the site of the primary lesion. Death results from recurring disease, hemorrhage, or from infection in the form of a pansinusitis, meningitis, or brain abscess. Only 10 (22 per cent) of the patients in the present series died of metastases—2 regional and 8 distant. In 6 instances the patients died of the effects of radiation therapy, 1 from hemorrhage and 5 from infection.

DIAGNOSIS

Delay in diagnosis is usually found in the history of a patient with a malignant tumor of the nasal cavity. The early signs of hemorrhage and nasal discharge may not incapacitate the patient, and so he is not particularly worried by these symptoms. Several weeks or months may pass before he consults his physician, who in turn may fail to recognize the true condition until the growth has become large enough to be visible in the anterior portion of the nose. Because of the early symptom of nasal discharge, cancer is often mistaken for an infection of the paranasal sinuses, and treatment for sinusitis may be carried out for several weeks while the tumor slowly increases in size.

As in all accessible tumors, a biopsy of any suspicious lesion of the nasal cavity is necessary before treatment can be planned. If cancer is clinically present, biopsies should be repeated until a positive report is obtained. Specimens should be taken from the base of a lesion, since the more superficial portions often show only inflammatory tissue. Bleeding which follows this procedure may be controlled with dry sterile packing. Since nasal polypi occasionally show neoplastic changes, such tissue should always be examined microscopically. In 5 cases of the present series cancer was not suspected but was revealed by a routine microscopic examination of nasal polyps before the patient applied to the Memorial Hospital.

Roentgenograms taken in the position usually employed for outlining paranasal sinuses will reveal the extent of bone destruction in cancer of the nasal cavity. Erosion of bone in the medial or inferior walls of the orbit indicates invasion by the neoplasm. Such information is of assistance in outlining the method of treatment.

Benign tumors of the nasal cavity are easily confused with cancer because of similarity in signs and symptoms. During the period covered by the present series only 7 cases, exclusive of nasal polyps, were seen at the Memorial Hospital. They include epithelial papilloma (2 cases), schneiderian membrane papilloma (1 case), mucous gland adenoma (1 case), schwannoma (1 case), and extramedullary plasmocytoma (2 cases). Some authors consider extramedullary plasmocytoma as a malignant lesion*, and it may easily be confused microscopically with lymphosarcoma. These lesions are particularly radiosensitive and respond best to small doses of external radiation. No single method of therapy is recommended for the other benign lesions, although papilloma can be effectively controlled by cauterization.

TREATMENT

General Hygienic Measures. Patients with cancer of the nasal cavity usually complain of discomfort resulting from obstruction in the air passages. Local applications of cocaine, followed by nasal irrigations, will sometimes give temporary relief. Usually, however, such treatment is not practicable because the obstruction extends throughout the anteroposterior diameter of the nasal fossa and even the slightest manipulation causes hemorrhage. At times the bleeding may be so severe as to require the ligation of the external maxillary artery. Patients who have suffered frequent or prolonged attacks of bleeding may need transfusions or daily injections of liver and

* A patient recently treated for extramedullary plasmocytoma at the Memorial Hospital now presents extensive bone metastases which on roentgenograms have the appearance of a plasma cell myeloma. This patient was twenty-five years of age on admission, and the histology of the primary tumor was only that of extramedullary plasmocytoma.

iron, either in preparation for operative procedures or during a course of irradiation. Local sepsis is present in almost every case of cancer of the nasal cavity. Wet dressings will reduce the infection, especially in the orbital cavity, but usually this symptom does not diminish greatly until several days after roentgen therapy has been started.

Radiation Treatment of the Primary Lesion. Such radiosensitive tumors as the transitional cell epithelioma, lympho-epithelioma, and anaplastic epidermoid carcinoma respond favorably to treatment by irradiation, either external or a combination of external and intracavitary. The series of cases herein reported has been collected over a period of thirteen years, during which time many changes have been made in methods of irradiation. With the improvement in roentgen therapy, interstitial irradiation is now seldom used.

In the clinic at the Memorial Hospital it is now customary to treat the radiosensitive tumors of the nasal cavity by high voltage roentgen radiation. The factors of such radiation are: 200–250 kv., 15–30 ma., filter 0.5–1.5 mm. Cu plus 1 mm. Al. Daily treatments are given over a period of approximately three weeks, the daily dose varying with the size of the field. For a field 5 cm. in diameter, a total dose of 4,000 to 5,000 r is delivered. If feasible, a peroral portal should be used as well as an external skin portal. The area to be irradiated should include the nasal cavity, the antrum, the ethmoidal region and the floor of the orbit on the affected side and, in some cases, the frontal sinus as well. It is important that the medial border of the field should extend beyond the midline of the nasal septum. To protect the uninvolved surrounding regions, an opening corresponding in size and shape to the field to be irradiated is made in a sheet of lead one-sixteenth of an inch thick (Fig. 4). If desired, intracavitary irradiation may be used to supplement the external irradiation. A single capsule or tandem of platinum filtered radon tubes encased in rubber tubing is inserted for a dose of 1,000 mc-hr. over a period of three to four days. In the series at the Memorial Hospital this method was originally used in nearly all cases, but recently irradiation and surgical methods have been employed in combination in the treatment of cancer of the nasal cavity; therefore, the intracavitary irradiation has not been feasible.

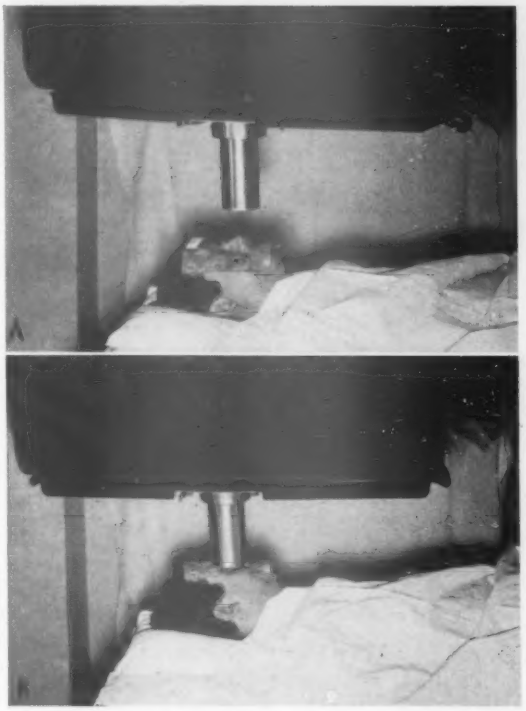

Fig. 4. *A*, lead shield with opening for irradiation of cancer of the nasal cavity. *B*, roentgen tube in place over lead shield.

Surgical Treatment of the Primary Lesion. In the more radioresistant lesions, such as low grade squamous carcinoma, adenocarcinoma, angiosarcoma or melanoma, irradiation measures alone are inadequate. In this group it is preferable to expose the nasal cavity surgically for removal of the fungating neoplastic tissue. An approach through the hard palate permits ready access to the affected region. An opening about 3 cm. in diameter can be made in the hard palate to expose the nasal cavity for growths arising in the floor of the nose, the septum, or the inferior turbinate. This

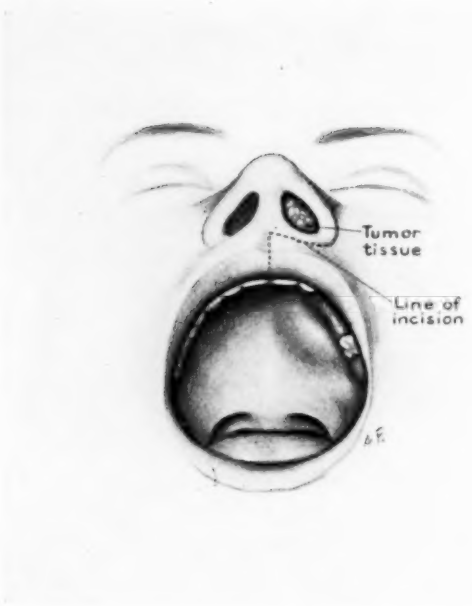

FIG. 5. External approach for exposure of the operative site in cancer of the nasal cavity (Weber or Fergusson).

opening can be cut in the mid-portion of the hard palate, maintaining if possible the contour of the alveolar ridge and leaving the teeth intact. However, if necessary, the floor of the antrum and a portion of the alveolar ridge may also be removed at the same time to give wider exposure.

A more satisfactory exposure of the nasal cavity tumors is obtained with the use of an external approach as in resection of the superior maxilla (Fig. 5). This incision has been designated both as the Weber[4] and as the Fergusson[4a] incision. The upper lip is split along the philtrum to a point just beneath the columella of the nose. The incision is then carried laterally to the nasolabial fold, then upward to the inner canthus of the eye. If necessary, this incision may be continued laterally, parallel to the lower eyelid at a distance of 0.5 cm. Thus, the soft tissues of the cheek can be reflected outward, exposing the anterior wall of the superior maxilla. The actual cautery is an aid in outlining the area of the hard palate to be removed. The overlying flap of the mucous membrane, however, is not preserved. By means of the cautery the incision is carried down to the level of the bone itself in a perfectly dry field. A hammer and chisel are used to separate the segment of bone outlined. In some instances it may be wise to remove also a portion of the alveolar ridge in order to obtain a larger opening for extirpation of the tumor. Only the mucous membrane of the nasal cavity then remains to be incised in order to expose the tumor itself (Fig. 6). A large part of the neoplastic tissue may be separated by means of the operator's index finger, and the remainder may be removed safely with a blunt curette. The middle and inferior turbinates should also be removed. No attempt should be made to preserve the periosteum in any area in which the extent of the disease is uncertain. Should bone be denuded, it will be covered later with granulation tissue or, in time, it will sequestrate. The actual cautery may be used in any areas where residual disease is suspected, but usually complete exenteration of the neoplasm may be obtained by means of the curette (Fig. 7). The cavity is packed with gauze saturated with Dakin's solution, and the cheek flap is then sutured back into po-

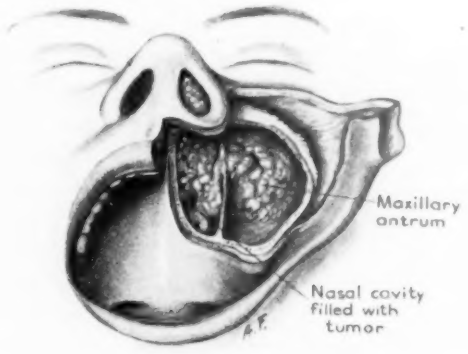

FIG. 6. The tumor in the nasal cavity is exposed after removal of the hard palate.

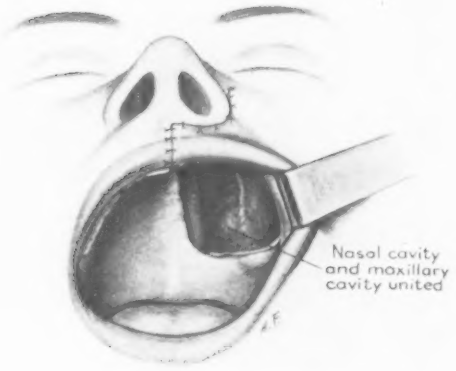

Fig. 7. The tumor in the nasal cavity has been removed and the skin incision closed. The opening left in the hard palate permits of frequent irrigations and examination of the nasal cavity.

sition. As a rule, only skin sutures of black silk or dermal catgut are required (Fig. 7). There are two reasons for maintaining the opening in the hard palate rather than effecting a plastic repair by means of the preserved mucous membrane: the area may be kept cleaner, and recurrent disease may be discovered earlier and treated more easily.

Tumors of the nasal cavity may also be approached through the gingivobuccal gutter anteriorly. The incision is made along the superior alveolar ridge high in the gutter for a distance of 3 to 4 cm. on either side of the midline (Fig. 8) as in the Partsch transphenoidal approach to the pituitary gland. The incision is carried upward to the level of the columella of the nose and then

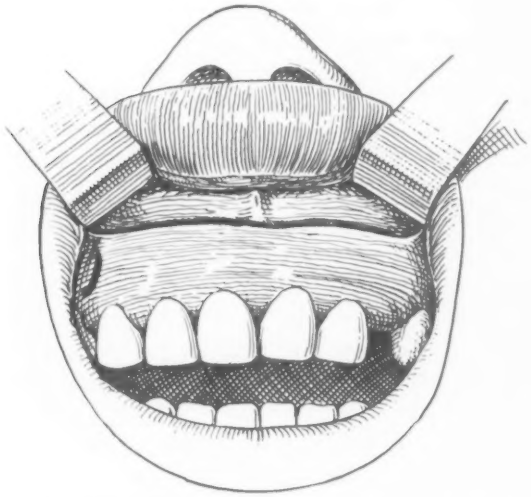

Fig. 8. Incision through the gingivobuccal gutter, as in Partsch's transphenoidal approach to the pituitary, for operative removal of cancer of the nasal cavity.

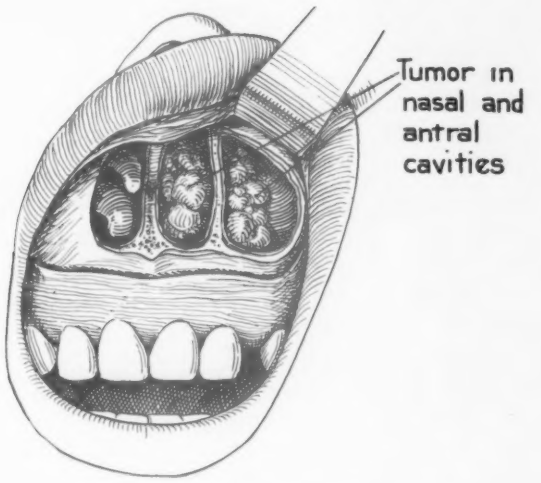

Fig. 9. The tumor in the nasal cavity and antrum exposed.

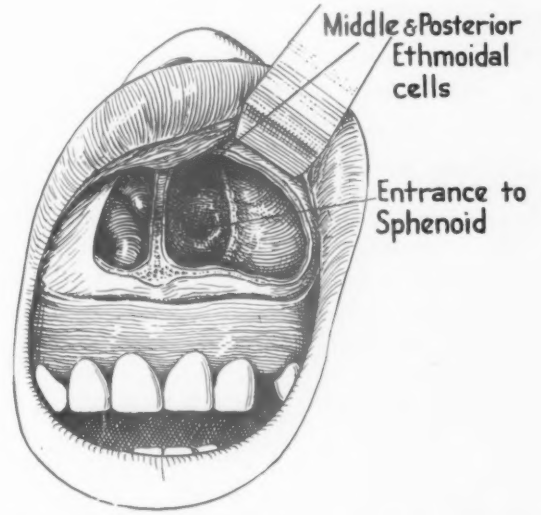

Fig. 10. Nasal cavity and antrum after tumor and party wall have been removed.

inward along the floor of the septum as far as necessary. Part of the septum may be removed to obtain adequate exposure, and a part of the antral wall on the affected side may be excised. The soft tissues of the lip and cheek and the external nose can then be retracted upward to permit the removal of the tumor of the nasal cavity (Figs. 9 and 10).

After excision of the tumor, the cavity is packed with gauze as in the operation previously described except that in this instance the free end is brought out through the anterior naris and the incision in the gingivobuccal gutter is closed with silk or dermal sutures. A disadvantage of this operation is that the nasal cavity is not as readily accessible for irrigation and examination.

Experience on the Head and Neck Service at the Memorial Hospital has proved that intratracheal chloroform is the anesthesia of choice in these operations since cautery is so often used. A preliminary ligation of the external maxillary arteries (two to three days before) will reduce the bleeding during the operative procedure.

Postoperative Care. Packing, inserted in the cavity at the time of the operation, should be left in place for twenty-four hours. The postoperative pain, part of which is due to the packing, may be controlled by the use of codeine and aspirin. Warm wet saline dressings reduce the edema of the soft tissues and relieve the patient's discomfort. The removal of the packing after twenty-four hours is facilitated by hydrogen peroxide irrigations. After irrigation with warm solutions of sodium chloride and sodium bicarbonate, the cavity is repacked with gauze saturated with a thin paste of zinc peroxide and hydrogen peroxide. Nasal feedings are required for several days and may be given with an ordinary French No. 16–18 urethral catheter. The patient should be taught as soon as possible to insert this tube himself. A high caloric, high vitamin diet must be maintained. The nasal feedings may be discontinued after a week or ten days, and dry packing inserted into the operative defect at mealtime permits mouth feeding. After six to eight weeks a special dental prosthesis can be constructed which will adequately close off the antrum and the nasal cavity from the mouth, permitting the patient to eat and speak without difficulty.

Postoperative Irradiation. In the clinic at the Memorial Hospital it is the policy to give a full course of high voltage roentgen radiation (250–300 r daily for a total of 2,500–3,000 r on a circular field 6–7 cm. in diameter over a period of ten days) a short time after the operation, especially if the tumor in the nasal cavity is epidermoidal or sarcomatous in nature and shows some degree of radiosensitivity. A shield such as that already described should also be used for this treatment.

Treatment of Recurrence. A positive biopsy is necessary before any treatment can be considered for recurrent cancer of the nasal cavity. In those patients treated originally by external irradiation only, additional treatment for recurrent disease must be limited to interstitial or intracavitary therapy. It is sometimes wise to administer such therapy in fractions, the total dose depending upon the amount of roentgen radiation previously given. In those patients treated by surgery, recurrences may be discovered early because of the opening in the hard palate. They may be cauterized if small and superficial, or implanted with gold filtered radon seeds if more extensive.

Treatment of Metastases. Cervical metastases from cancer of the nasal cavity are treated according to the principles applied to secondary involvement from other intraoral growths. The treatment is selected according to the requirements of the individual case. Irradiation—external, interstitial, or a combination of the two—is the method to be employed in metastases from such radiosensitive histopathologic growths as transitional cell carcinoma or lymphoepithelioma. The specific details of the irradiation technique are not within the

scope of the present report. Neck dissection is suitable in those cases of epidermoid carcinoma in which the primary lesion is controlled, the metastases unilateral with capsule intact, and the general condition of the patient favorable. It is only the occasional case, however, in which these requirements are fulfilled.

COMPLICATIONS

Secondary anemia may occur with a prolonged course of roentgen therapy. Liver and iron as well as vitamin B_1 should be given perorally or intramuscularly. Supplementary high caloric feedings should be started early in the course of irradiation before there is loss of weight. If necessary these feedings may be given through a nasal tube inserted through the unaffected side of the nose.

Nasal irrigations and albolene sprays should be started soon after radiation therapy is completed to prevent the mucous membranes of the nose from becoming dry and crusted. These local treatments may also prevent the development of radionecrosis, which is the most serious complication of treatment. If radionecrosis occurs, the patient should be hospitalized. The cavity should be cleaned twice daily with a power spray and the loosened necrotic tissue cut away. Gauze packing saturated in a thin paste of zinc peroxide and hydrogen peroxide inserted into the cavity will decrease the infection caused by anaerobic organisms. These packs should be inserted twice daily and left in place from four to six hours. Infection which accompanies radionecrosis may spread rapidly and involve the eye, so that it may become necessary to enucleate an orbital cavity which had previously been unaffected. Hemorrhage may occur from areas of radionecrosis and, in spite of packing and ligation of the afferent arteries, may terminate fatally.

In recent cases, chemotherapy has proved valuable in the treatment of infection which results from nasal obstruction as well as that which accompanies radionecrosis. Since the organisms in the nasal cavity are predominantly streptococcus and staphylococcus, sulfanilamide and sulfathiasol are the most effective.

Table II

FACTORS INFLUENCING THE FIVE YEAR CURE RATE IN 35 CASES OF CANCER OF THE NASAL CAVITY OBSERVED AT MEMORIAL HOSPITAL 1928 TO 1935, INCLUSIVE

	Total Number of Cases	Number of Five Year Cures	Percentage of Five Year Cures
Age in years			
Below 40	7	3	43
40 to 49	5	1	20
50 to 59	12	2	17
60 and over	10	2	20
Not given	1	0	0
Sex			
Male	24	6	25
Female	11	2	18
Metastases			
None at any time	23	8	35
On admission	5	0	0
Developed after admission	7	0	0
Some time during course	12	0	0
Histopathology			
Squamous carcinoma Grade 1	2	1	50
Squamous carcinoma Grade 2	11	3	27
Squamous carcinoma Grade 3	2	0	0
Squamous carcinoma Grade 4	1	0	0
Squamous carcinoma ungraded	1	0	0
Transitional cell carcinoma Grade 2	2	0	0
Transitional cell carcinoma Grade 3	2	0	0
Spindle cell carcinoma	2	0	0
Lympho-epithelioma	3	2	67
Adenocarcinoma	7	1	14
Fibromyxosarcoma	1	0	0
Angiosarcoma	1	1	100

PROGNOSIS

The factors which influence the prognosis in any form of cancer are the extent of dis-

ease on admission, the presence of metastases, the histopathology of the tumor, and the general condition of the patient. In Table II are given some of the factors of prognosis in the present series.

TABLE III

FIVE YEAR END-RESULTS IN CANCER OF THE NASAL CAVITY, MEMORIAL HOSPITAL 1928 TO 1935, INCLUSIVE

This series consists of all patients with histologically proved cancer of the nasal cavity, both early and advanced, admitted during the specified period. Only those patients are excluded who, for any reason, were unable to return for treatment, palliation and observation in the out-patient department or who were lost track of within the first month after no more than one or two visits (clinic shoppers).

Total number of cases		37
Indeterminate group:		
Dead as a result of other causes and without recurrence	1	
Lost track of without recurrence	1	
Total number of indeterminate results		2
Determinate group:		
Total number minus indeterminate group		35
Failures:		
Dead as a result of cancer	26	
Living with recurrence	1	
Total number of failures in treatment		27
Successful results:		
Free from disease after five year or more		8
Net five year end-results:		
Successful results divided by determinate group (8/35)		23%

The duration of symptoms must necessarily be a prominent factor, and in an area such as the nasal cavity where the early symptoms are ignored, it is inevitable that the lesion should be fairly well advanced before treatment can be instituted. In cases where the disease is limited to the nasal cavity, the prognosis is fair, but invasion of the floor of the orbital cavity, as may be shown by roentgen examination, signifies involvement of the ethmoids or the maxillary antrum, or both, and the possibility of controlling the disease diminishes. Disease which has existed for many months is accompanied by debility, especially in the aged.

It has been noted that cancer is especially malignant in young people, but this observation is not in accord with the present series of nasal cavity tumors. Of the 8 patients surviving for more than five years, 3 were boys aged six, ten and sixteen years, respectively. The histopathology of these tumors was angiosarcoma, lympho-epithelioma and mucous gland adenocarcinoma, respectively.

The cure rate in women (18 per cent) was slightly less than in men (25 per cent) but the number of cases is too small to give any significance to this deviation from the findings in other forms of intraoral and pharyngeal cancer, in which the cure rate is higher in women than in men.

No patient with metastases, either on admission or developing later, has survived. It may be concluded that with the occurrence of metastases, the chances of controlling a cancer of the nasal cavity are reduced to less than 1 per cent.

Of the 8 surviving patients, 4 had squamous carcinoma, 2 lympho-epithelioma, 1 adenocarcinoma, and 1 angiosarcoma. No significant conclusions regarding prognosis based on histopathologic type can be drawn from such small groups.

END-RESULTS

It has been impossible to find in the literature any comparative statistics on the cure rate of malignant tumors of the nasal cavity. Ringertz[5] reviewed a series of 391 malignant tumors of the nasal and paranasal cavities collected in Stockholm. Treatment for the most part was by some form of radiation, but since the basis of classification was pathologic, the end-results for a group originating in any one anatomic area have not been tabulated.

The net end-results in the present series are given in Table III. Of all the patients in the present series, only 37 have been observed for five years or more. Two of these died of other causes after a year's freedom from disease and may be considered as indeterminate cases. The determinate group, therefore, consists of 35 patients, of whom 8 are living and free of disease for at least five years, giving a net cure rate of 23 per cent.

SUMMARY

A series of 65 cases of cancer of the nasal cavity has been analyzed from the standpoint of histopathology, clinical course, treatment and end-results. Indications for surgical and radiation treatment are outlined, and the results tabulated. In the group of patients observed for five years or more, the cure rate is 23 per cent.

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IRRADIATION PULMONARY FIBROSIS*

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LUNG changes in the nature of a lung reaction to inflammation may occur as a result of irradiation. Since irradiation is widely employed as an adjunct to surgery in cancer of the breast, especially with axillary node involvement and as a palliative procedure in late or inoperable cases, it seemed pertinent that some estimate of the possible incidence of pulmonary fibrosis be made. Such a study involves so many roentgenologic and pathologic variations and inconsistencies that opinions, interpretations, and conclusions present numerous possibilities of error and controversy.

Why do some patients show roentgenologic evidence of fibrosis two to three months after 1,600 to 2,000 r (measured in air) to the skin of each of three or four portals, while other patients show no roentgenologic changes for as long as eight to twelve months after irradiation, and still others no detectable roentgenologic change for as long as five to ten years? Furthermore, why do other patients of approximately similar physical types show roentgenologically normal lungs when a second cycle of 1,400 to 2,000 r (measured in air) is given to the skin surfaces of each of three or four portals, and why are there no lung changes in many patients receiving as much as three and even four cycles of roentgen treatment given at six to eight week intervals averaging total doses of 3,000 to 6,000 r (measured in air) to each of three or four skin portals within six to twelve months?

In other words, how and when may irradiation fibrosis occur? What daily intensity, rate, and total dose are permitted by actual clinical experience so that, theoretically, the patient may obtain the greatest advantage and benefit of any virtue which irradiation may be expected to offer with the least risk of resulting lung fibrosis? If and when fibrosis occurs, what may be the contributing factors, symptoms, and effects on the life and general health of the patient? What premises shall determine irradiation pulmonary fibrosis?

It was thought that these questions could be decided simply and with mathematical precision from a list of about one thousand cases of cancer of the breast in the records of the Radiological Department of the Philadelphia General Hospital. This study, however, soon became difficult and intricate because many patients did not receive the full complement of a predetermined plan of irradiation as a result of advanced disease and some were too ill to tolerate irradiation. Many were postoperative recurrent cases on admission with extensive roentgenographic evidence of pulmonary or skeletal metastases. The complexities were increased when the clinical course of the completely treated cases rapidly became unfavorable. It was especially discouraging to discover a lack of serial roentgenograms for comparative evaluations of progressive lung changes, particularly among patients three to twelve months after treatment with pulmonary infiltrations that were unmistakably effects of metastatic cancer.

Groover, Christie, and Merritt[4] (1923) described with such detail and clarity the symptoms, pathology, and clinical effects of irradiation fibrosis that little remains to be said except concerning technical procedures and serial studies.

Evans and Leucutia[3] (1925) reviewed 80 cases of their own and found the incidence rare unless a repetition of large doses was necessary, when 80 per cent of the cases showed fibrosis if the dose exceeded 140 per cent of the skin unit dose. They showed that lung changes are dependent on the quantity of radiation rather than on its wave length.

In 1932 Desjardins[1] also gave an elabo-

* From the Radiological Department, Philadelphia General Hospital, Philadelphia, Pa. Read at the Twenty-fifth Annual Meeting, American Radium Society, New York, N. Y., June 10–11, 1940.

rate account of clinical, roentgenologic, and technical factors in post-irradiated lungs and was able to detect lung changes in only 2.5 per cent of several hundred cases in which the thorax received from 800 to 1,000 r (measured in air), but he had never seen a lung reaction after 600 r.

In 1934 McIntosh[5] discussed 4 cases showing varying degrees of pleuropulmonitis one to two months after irradiation of the thorax together with accurate depth dose estimations ranging from 2,000 to 4,000 r (measured in air) through the mid-lung region. Possible influence of age and arteriosclerosis were suggested as complicating factors.

In 1936 Downs[2] studied the combined effects of irradiation, and in 53 cases autopsy findings showed only one instance of fibrosis. Other cases of fibrosis complicating tuberculosis and metastatic cancer were found, but clear-cut differentiation was not possible. Downs also was impressed by lung vulnerability to irradiation as a result of acute and chronic infection and arteriosclerosis.

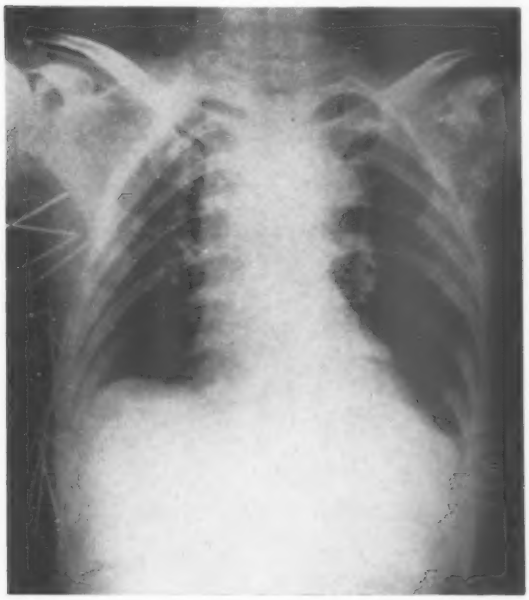

Fig. 1. A. S., aged fifty-seven. Interstitial radium needles, 10,726 millicurie-hours in seven days. Filter 0.5 mm. platinum. Treatment on July 5, 1934.

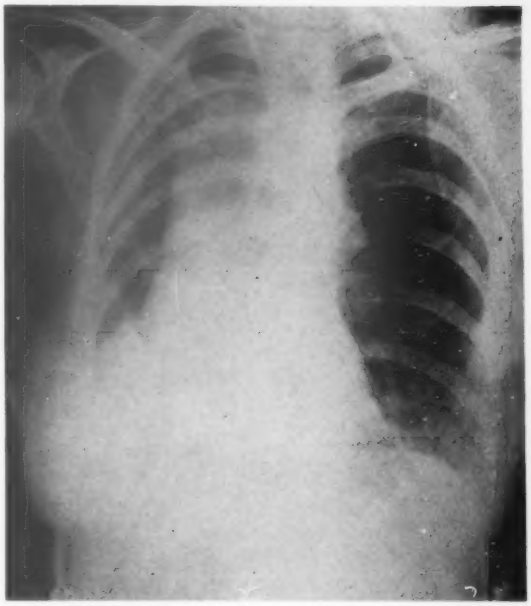

Fig. 2. A. S. Atelectasis seven months later, January 17, 1935. Died on February 10, 1936. No autopsy.

Warren and Spencer[6] demonstrated that the amount of radiation necessary to produce histologic changes varies greatly. They made histologic studies of the lungs of an unselected series of 398 autopsied cases of cancer primary between the diaphragm and neck and found 29 cases (7 per cent of the entire group, 12 per cent of 234 irradiated cases) which showed changes referable to irradiation of the lung. They did not believe that the existence of pulmonary metastases had any significant relation to the development of irradiation changes. They also described roentgenographic appearances which serve to differentiate the process of irradiation fibrosis from infiltration of metastases.

The routine technique of high voltage roentgen treatment of the thorax for inoperable cases and for preoperative or postoperative treatment of cancer of the breast in the Radiological Department of the Philadelphia General Hospital is as follows: 200 kv., 0.5 mm. copper filter, 25 ma., 50 cm. distance, half-value layer 0.9 mm. copper, 47 r per minute, and 16×20 cm. portal. Four portals are used, two including

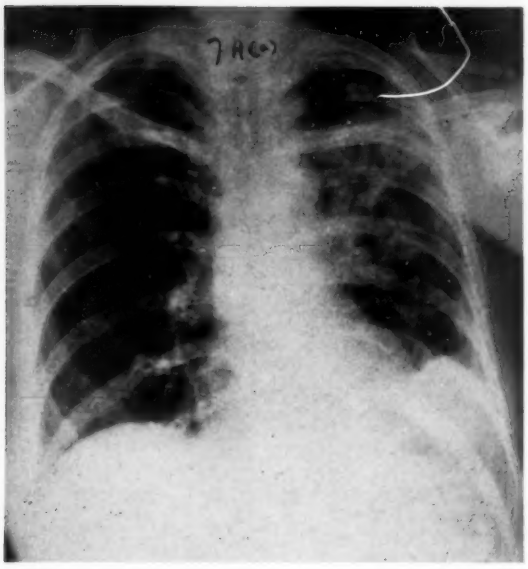

FIG. 3. N. C., aged fifty-nine. November 16, 1932. Fibrosis after 4 × 4,200 r in three cycles, April, June, and October, 1932.

neck, supraclavicular and infraclavicular and breast regions, and one portal (in large individuals two) including the lateral chest, axilla, and lateral half of the breast. In a small or thin patient one axillary portal is frequently sufficient.

All three or four portals are treated at the same sitting (3 or 4 × 200 r, measured in air) at the rate of three treatments a week for a total of eight or ten treatments, or 1,600 and 2,000 r (measured in air) to each of three or four portals for thin and stout individuals respectively.

According to the phantom measurements by Weatherwax and Robb[7] in normal lungs, the routine cross-fire technique herein described to include the skin area of the anterior chest and neck and the lateral chest, breast, and axilla admits an intensity of radiation throughout the mid region of the lung of the side treated almost equal to the skin intensity. Easily 40 to 60 per cent of the surface intensity of a single portal reaches a depth of 10 cm., and the intensity at this depth equals the surface dose when cross-fire technique of two beams of radiation at right angles is used as described above. In an average individual the lung dose is approximately 2,000 r (air) or 3,000 r (tissue dose) for the first cycle, and approximately 50 per cent of this intensity for each of the second and third cycles.

Obviously the distribution of the radiation intensity varies for the apex and base regions. This difference is not appreciable for practical purposes because of the difference in the musculature and soft structures about the shoulder girdle. The thickness of this region also varies in preoperative and postoperative cases, and in the presence of axillary, infraclavicular, and supraclavicular metastases the variation is still greater.

While the predetermined plan of treatment in each case involves 1,600 to 2,000 r (air) per skin portal, or a lung tissue dose of 2,400 to 3,000 r, in many instances treatments were discontinued because of failing health and weakness or failure to keep appointments. Many interruptions were due to constitutional radiation reactions. Serial films in this study include cases that received as little as 1,000 to 2,000 r throughout the lung region. Approximately 182 of 273 patients received two or more series of

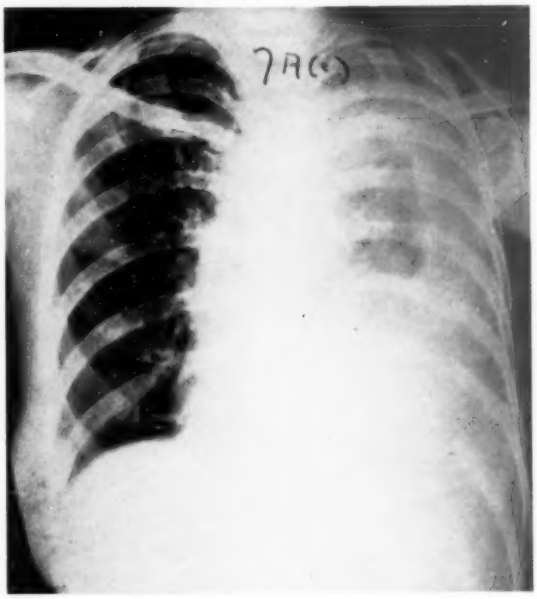

FIG. 4. N. C. February 28, 1933. Progressive involvement fourteen months later. Died on April 19, 1933.

treatments, usually a duplication of the first cycle, 1,600 to 2,000 r (air) to each of three or four skin portals, or 2,000 to 3,000 r (tissue doses) throughout the lung structure. A third series of treatments was given in 51 cases, and a fourth series in 31 cases. Usually the third and fourth series involved a total of 1,000 r (air) to each of three or four skin portals.

Between the first and second series the interval averaged six to eight weeks, and between the third and fourth series of treatments eight to twelve weeks. Two cycles were given routinely in cases of axillary lymph node involvement. When more than two cycles were necessary, treatments were considered as only palliative.

Tangential direction of the beams of radiation will avoid inclusion of much of the lung structure in preoperative irradiation, but this technique must include some part of the lung if it is to adequately include the deeper lying tissues of the chest wall to sterilize the permeating or infiltrating extensions of a cancer of the breast. Tangential irradiation may minimize but will not obviate the possibility of fibrosis.

Fig. 5. E. W., aged sixty-three. Fibrosis eighteen months after 4 × 1,400 r. Autopsy on February 25, 1935. Fibrosis and carcinoma.

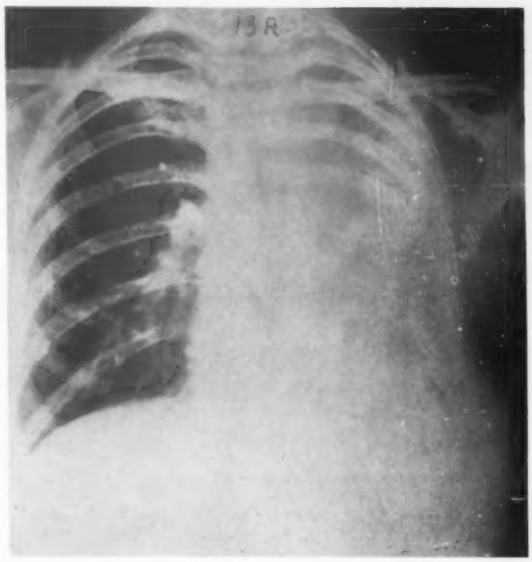

Fig. 6. B. B., aged forty-three. One year after four series of irradiation, January and October, 1933, and January and April, 1934, with doses of 1,000, 1,800, and 1,200 r to each of four skin portals, or a total per skin portal of 5,400 r. Film made June 1, 1934, shows atelectasis eighteen months after first treatment. Autopsy: cancer and fibrosis.

It is reasonable to visualize a lung reaction to inflammation as a result of irradiation commensurate with the intensity of the skin reaction as discussed by Groover, Christie, and Merritt in 1923. A dose of 2,000 r (air) to a skin portal 16×20 cm. given at the rate of 200 r three times a week will result in a variable degree of skin reactions approaching desquamation in 25 per cent of cases. A desquamating reaction requires three to six weeks for healing. Roentgenograms showed a faint and borderline haze or clouding in 7 of 29 cases two to four weeks after treatment with 2,000 r (air) to each of four portals, and no roentgenologic change one to two months later. The altered density was so questionable in these cases that it seems justifiable to assume that the rate, intensity, and total dose used are relatively free of serious hazard of so-called "acute lung reactions" or pneumonitis.

The acute lung reactions described variously as pleuropulmonitis and pneumonitis

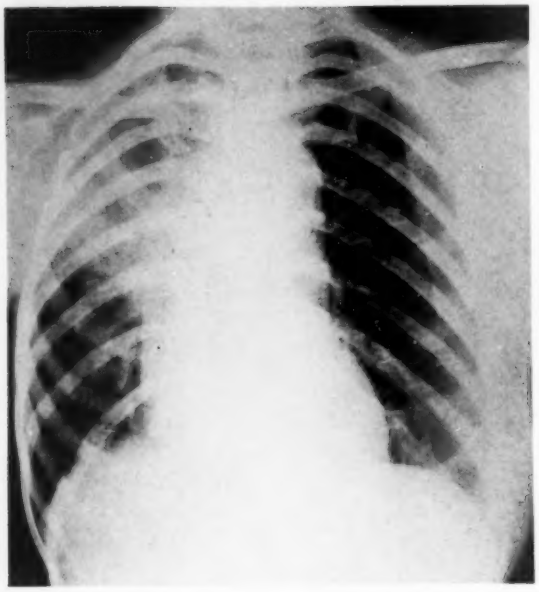

FIG. 7. E. C., aged thirty-three. Fibrosis five years after four series of roentgen treatments given August, October, December, 1928, and March, 1929, for a total of 4,800 r to each of two skin portals. Film made June 6, 1934. Autopsy: irradiation fibrosis. Cancer of right lung not demonstrated. Death August 24, 1935, from pneumonia. No local recurrence.

blending the roentgenographic appearance of a pneumonic consolidation are rare complications of the present-day technique with relatively small intensities of 100 to 200 r per portal and total doses of 1,000 to 2,000 r (air) per skin portal. This review has encountered only questionable roentgenographic evidence of acute lung reactions occurring concomitantly with the skin reactions—within one to six weeks after completion of treatment. Because of the slight incidence, such a complication was considered as a possible effect of underlying pathologic conditions—infection or cancer or effects of so-called "massive" dose technique, 500 r or more per portal at one sitting.

The roentgenologic appearances of irradiation pneumonitis or so-called acute reaction are not necessarily permanent. Usually altered densities of sufficient extent to be amenable to roentgenographic demonstration as a result of edema or a profound "congested state" of the lung tissue are actual effects of an acute pneumonitis or pleuropulmonitis, and these alterations may resemble pneumonic consolidations.

On the other hand, pneumonitis probably occurs more often than is demonstrated roentgenographically because irradiation fibrosis is essentially a late effect of a pneumonitis. This process is a simple natural tissue evolution of the well known and easily recognized microscopic picture of edema, endarteritis, fibrosis, hyalinization, and obliteration of the finer capillary blood vessels. Theoretically, every case of irradiation fibrosis is a natural concomitant of a pneumonitis, even though the acute reaction is rarely demonstrable clinically or roentgenographically, and such evidence in this experience has been permanent.

In the early days of so-called "high voltage roentgen rays" (200 kv.) when the more powerful tubes and equipment gave new hope and renewed enthusiasm, there was a marked tendency to give treatments at a faster rate than is the custom today, and acute lung reactions were frequently reported. The symptoms of cough, pain, and

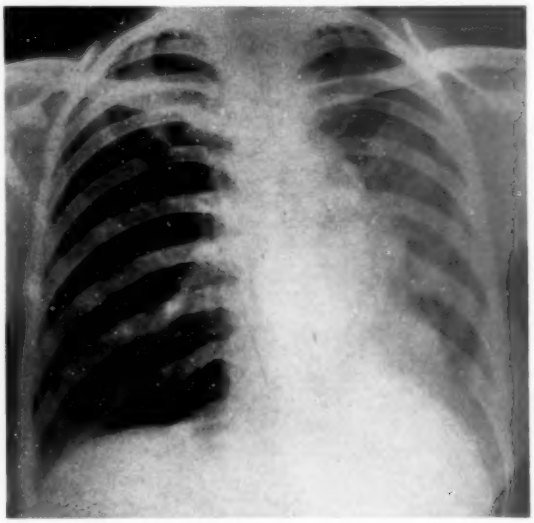

FIG. 8. E. K., aged forty. Roentgenogram made August 25, 1936, six months after treatment during February, 1936, 4 × 2,000 r, and April, 1936, 4 × 1,400 r. Autopsy on June 20, 1938, showed fibrosis and carcinoma.

dyspnea so often referred to as a result of an acute irradiation pneumonitis have never been encountered in sufficient degree to be recorded in the records of any of our patients. When these symptoms were shown in the records the subsequent clinical course invariably demonstrated the presence of metastatic cancer.

Cough, pain, and dyspnea in the late lung reactions with extensive roentgenographic changes of fibrosis and varying degrees of atelectasis occurred frequently, but these were interpreted clinically as effects of cancer because the subsequent course and termination of the case was that of metastatic cancer. Such an unqualified interpretation was not wholly justified because irradiation fibrosis complicating metastatic cancer may be the sole or aggravating factor of cough.

Preliminary roentgenograms were frequently negative, but because some cases showed rapid development of fibrosis with resulting atelectasis within three months with variable total intensities of radiation, the question of metastatic cancer existing as perivascular or peribronchial lymphatic permeation before treatment was considered. Indeterminate appearances of accentuated lung markings are variables of normal lungs in different physical types of individuals. Such appearances exist where there is a reasonable question of minimal effects of chronic infection or changes resulting from advancing age, arteriosclerosis, or fibrosis of passive pulmonary congestion of cardiac origin. There are many potential possibilities of pathologic entities to complicate interpretations of such phenomena in human beings. One can only estimate the incidence of definite roentgenographic effects according to subsequent clinical course and known technical procedures of irradiation. It would seem that metastatic cancer to the lungs may exist to a considerable extent and not be amenable to roentgenographic demonstration except as appearances that may simulate minimal fibrotic characters of normality or minimal pathology of infections.

Fig. 10. R. F., July 29, 1937. Marked pneumonitis and fibrosis seven months after first series and three months after second series given April, 1937, 4 × 2,000 r or a total of 4 × 4,000 r.

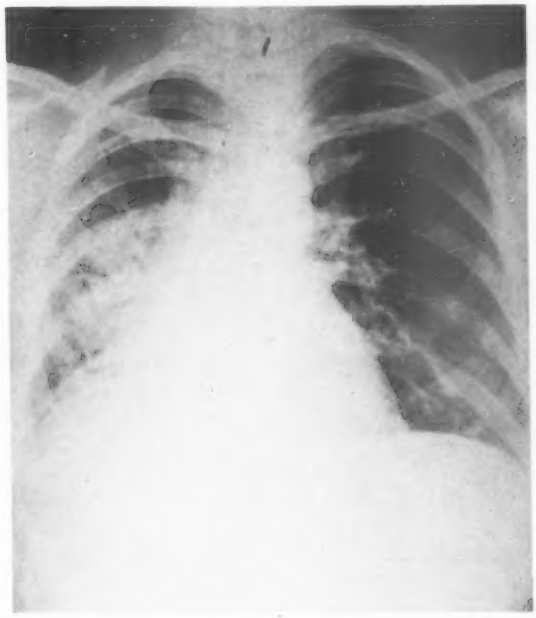

Fig. 9. R. F., aged forty-seven. January 12, 1937, minimal fibrosis two months after 4 × 2,000 r given November, 1936.

Many times roentgenologic reports would describe "typical roentgen appearances of irradiation fibrosis" of a part or all of the opposite lung, while the lung field of the

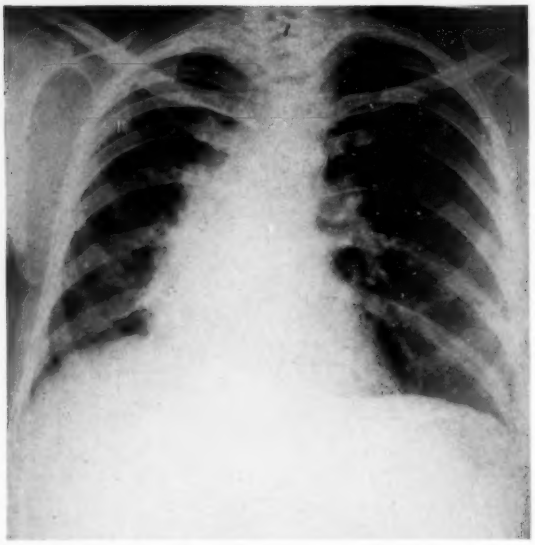

Fig. 11. R. F., July 14, 1938. Subsidence of pneumonitis and stationary atelectasis eighteen months after treatment. Persistent cough. Died May 20, 1940, of cancer.

treated side remained clear over periods of six to twenty-four months. These changes were always proved roentgenographically to become progressive and characteristic of metastatic carcinoma, and were often confirmed at autopsy. Warren and Spencer[6] demonstrated that acute reactions may be readily differentiated from infectious lesions by the distinct linear bands associated with the traction of the mediastinum. This usually appears after about the same time interval following irradiation that one would expect the height of the cutaneous reaction, although the time is somewhat variable. They also considered that these distinctive changes served to differentiate the process from infiltration of metastases.

Autopsy studies were done in 41 cases with records of satisfactory serial roentgenograms and irradiation of one or more cycles. The postmortem findings were valuable and important because the preponderance of this material involved late cases and many roentgenograms presented difficulties with respect to irradiation fibrosis or atelectasis and metastatic cancer. There were 62 of 273 cases interpreted as irradiation fibrosis. Some of these cases presented roentgenographic evidence of pulmonary metastasis before irradiation. Serial roentgenograms in these cases showed unusual and sometimes astounding evidence of fibrosis development with resulting atelectasis after variable intensities of 1,600 to 2,000 r and sometimes only after two to three cycles of 2,000 to 6,000 r. These effects were out of proportion to the variable metastatic manifestations in non-irradiated cases. There was likewise a rapid and almost fulminating development of contracture and increased density of the lung structure. These changes remained localized in the irradiated lung even in many instances where the roentgenograms before irradiation showed approximately similar bilateral infiltration. The great difference in time and degree of fibrosis with identical doses in postoperative cases was interpreted as a possible difference in degree of extent of metastatic carcinoma existing at the time of irradiation. It is entirely possible that such dif-

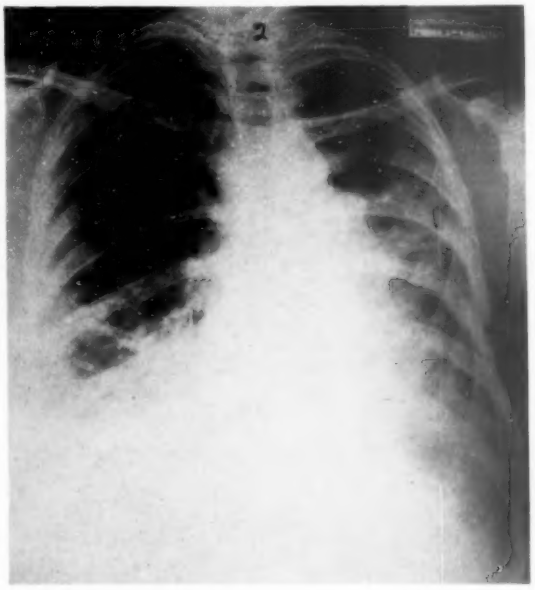

Fig. 12. R. H., aged forty-two. January 14, 1940, eight years after 3 × 3,680 r given April to December 1930, and 3 × 2,400 r given December, 1932, for clinical evidence of recurrence. Osteoradiation necrosis and pathological fractures of left seventh and eighth ribs. Symptom-free May 10, 1940, except for dry cough.

ferences may be the result of difference in the cellular character of various tumors, as well as some as yet unrecognized difference in the bed of the tumor in different individuals.

Of the 62 cases considered as irradiation fibrosis, 41 autopsied cases showed evidence of metastatic cancer. Histologic studies by Dr. P. Custer failed in a few instances to reveal cancer in the irradiated lung, but the opposite lung or pleura revealed microscopic evidence of metastatic cancer. The irradiated lungs were studied especially to substantiate the roentgenographic interpretation of irradiation fibrosis complicating metastatic cancer. In a few instances the histologic studies did not show cancer, but the entire lung was not always sectioned. A separate pathologic investigation is in progress.

Fibrosis may appear in the roentgenograms as slight or marked. The changes are usually strand-like fibrous infiltrations of variable extent progressing to a stage of typical atelectasis. There may be small or large, irregularly outlined, patchy areas of density and haze of the peripheral zones resembling thickened pleura. Diaphragm outlines are frequently indistinct and often become elevated. Effusion has generally been a complication of proved metastatic cancer, but any of the above changes may be an effect of cancer.

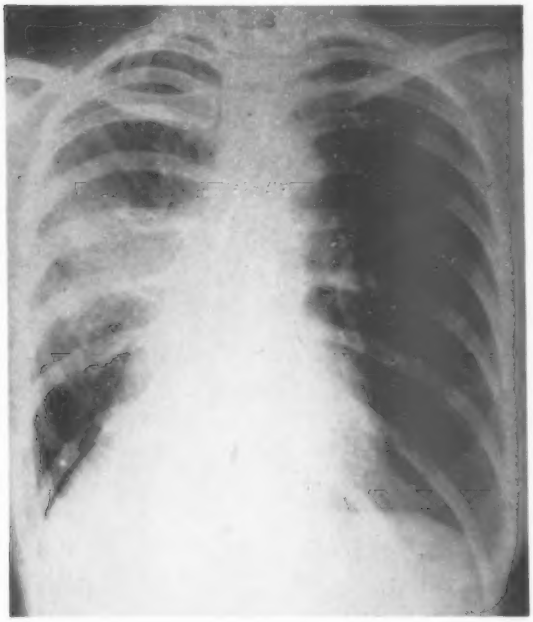

Fig. 13. M. G., aged forty-three. February 9, 1939. Fibrosis and atelectasis six months after 3×1,600 r.

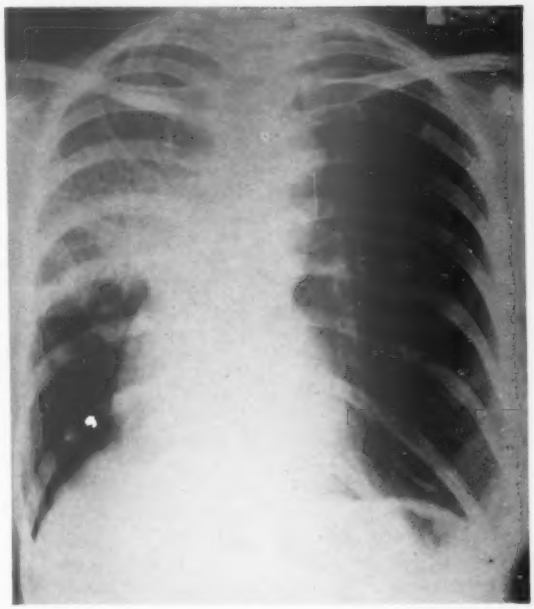

Fig. 14. M. G. April 18, 1940. No appreciable change twenty months after treatment. Pain and cough.

Since metastatic cancer to the lungs frequently resembles irradiation fibrosis, serial roentgenograms served to demonstrate lung changes of metastatic cancer progressively approaching atelectasis to a more striking degree than is usually noted in cases without irradiation.

The roentgenographic appearances of fibrosis may occur with the organization of lobar pneumonia or bronchopneumonia, chronic lung infections frequently referred to as upper respiratory in origin, tuberculosis, abscess, gangrene infarct, and particularly incipient metastatic cancer with permeating perivascular and peribronchial infiltrating characters.

The character or intensity of fibrosis in any one of these conditions may at some stage of development simulate that of an-

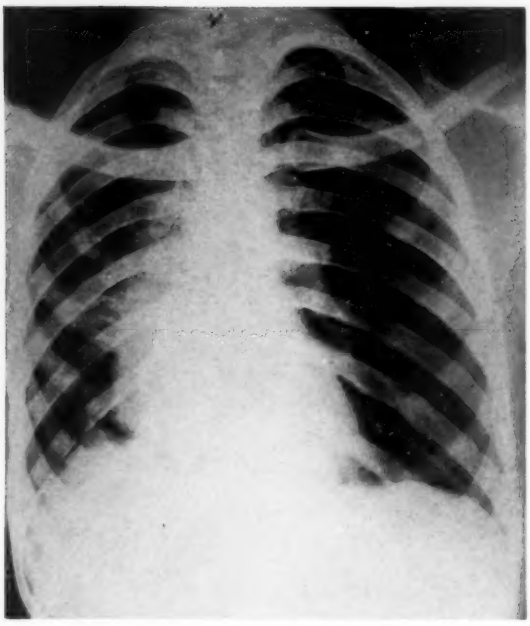

FIG. 15. B. G., aged thirty-four. September 21, 1938. Fibrosis and atelectasis seven months after treatment October, 1937, to February, 1938, with 4 × 2,000 r.

other of the processes. So-called interstitial pneumonia or pneumonitis with fibrous tissue production of the interalveolar and peribronchial connective tissue is a common change in pneumoconiosis and passive pulmonary congestion of cardiac origin.

Warren and Spencer[6] interpreted increased radiolucency of the chest as the earliest roentgenographic evidence of an irradiation reaction followed, after an interval of a few weeks, by an increased density, part of which is apparent as discrete bands, with displacement of the trachea, heart, and mediastinal shadow toward the affected side. These effects within the time interval of irradiation serve to differentiate changes resulting from infection.

In the absence of fibrosis and atelectasis, the most important early sign in this series of cases was elevation of the diaphragm with subsequent blurring and indistinctness of its outline, followed later by varying sizes of patchy infiltrations to progressive widespread involvement and atelectasis.

The most valuable criteria for establishing the possible incidence of irradiation fibrosis following certain doses of radiation are changes in serial roentgenograms of patients whose subsequent clinical course over a period of two or more years following demonstration of fibrotic changes precludes reasonable inference of metastatic cancer. On the other hand, metastatic cancer may become manifest at any time.

The changes varied in degree and extent of involvement from small to large infiltrations and atelectasis, and appeared within three to eighteen months. Doses of 2,000 r (air) sometimes showed degrees of fibrosis comparable to the effects seen after a second cycle of an additional dose of 2,000 r (air), but there were instances of marked fibrosis with one cycle of 1,600 to 2,000 r far in excess of the fibrosis resulting from two cycles of a total of 4,000 r (air) per skin portal.

Every case was summarized when there was evidence of one or more completed cycles of roentgen-ray treatment. The Social Service Department has maintained an extraordinary record of follow-up in almost

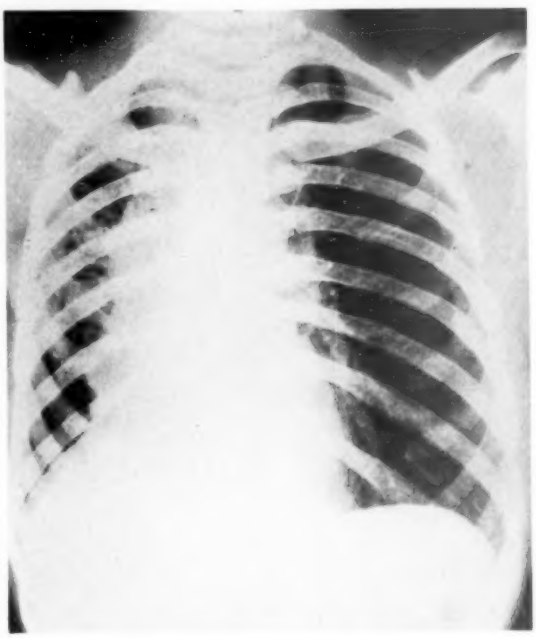

FIG. 16. B. G. March 20, 1940. Progressive involvement of fibrosis and atelectasis two years after treatment. Symptom-free. No cough.

every instance. Details as to dates of admission, operation, treatment, recurrence, roentgenograms, deaths, autopsies, etc., to be used for subsequent statistical studies, were tabulated systematically together with notes regarding the present condition of active cases. No case was considered unless there were serial roentgenograms at least three to six months after irradiation. The lungs and skeletal system are studied roentgenologically routinely before institution of any form of treatment. Serial roentgenograms are made at one, three, and six month intervals according to the clinical status of the case.

Material was discarded when there was evidence of pulmonary metastasis unless the physical condition of the patient permitted the administration of one or more cycles of irradiation and the longevity cycle was sufficient to permit an evaluation of pulmonary changes in serial roentgenograms of several months or more.

Minimal fibrotic changes may not be detected in the roentgenogram except as contracting lung fields with elevation of the diaphragm and minimal retractions of the mediastinal tissues.

It is interesting to note that there were 94 inoperable cases in the entire group of nearly a thousand cases with a life cycle averaging sixty-four months from the institution of irradiation.

Postoperative cases without axillary node involvement received only one cycle of irradiation. Only 14 per cent of the operable cancers of the breast at the Philadelphia General Hospital were microscopically free of axillary node metastasis. All cases with axillary node involvement were given one or more cycles of irradiation. There were 274 cases referred from clinics of other institutions for postoperative treatment, but these were late operable cases because the average life cycle from the time of admission was only twenty-eight months. Many of these cases were seen as late as six to twelve months after radical operation and usually manifested evidence of local recurrence or glandular or pulmonary metastasis. Many of these served as excellent criteria for estimating the intensity and rate of irradiation fibrosis development by comparison with lung changes from metastatic cancer in non-irradiated cases.

Fig. 17. A. H., aged sixty-seven. April 13, 1939. Inoperable cancer left breast, showing complete atelectasis five months after 4 × 2,000 r. On March 14, 1940, left breast showed progressive involvement with additional extensive involvement of right breast.

The clinical course of the cases presented an important correlation. This was regarded as unusually favorable when there was improvement in health and strength; stationary status of béing clinically symptom-free; stationary with recurrence or metastasis; or slow or rapid retrogression of health and strength with clinical evidence of progressive extension of the disease.

Roentgenographic changes were manifested in variable degrees from two to twelve months after treatment. Regardless of the amount of treatment, there was a great difference in the extent of involvement and the rapidity of development. Sometimes infiltrations of fibrosis occurred to a very slight degree in three months, and the same extent and character of change

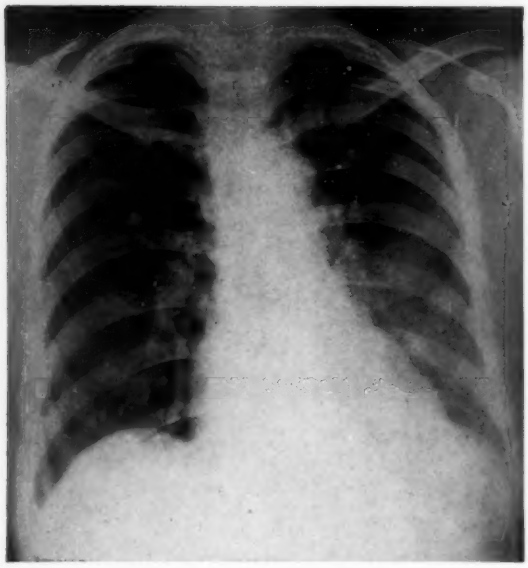

FIG. 18. F. S., aged fifty-nine. October 4, 1939, three and a half months after 4 × 2,000 r given July, 1939.

was often noted only after twelve months with the same rate and intensity of irradiation in individuals of similar physical types.

The best evidence of irradiation pulmonary fibrosis was obtained from a study of serial films of active cases one to ten years after operation and irradiation. The greater the duration of life, the more likely are the chances of excluding pulmonary effects of metastatic cancer. The clinical course of cases with permeating or peribronchial metastatic manifestations was frequently very favorable over indefinite periods of time. The diagnosis and degree of involvement were not always definitely recognizable until there was progressive involvement.

Records of one or more cycles of roentgen treatment were available for nearly 500 cases, but of these only 273 had satisfactory serial roentgenograms. The number of serial roentgenograms varied. Approximately 107 patients were studied at one to six month intervals, and 31 had roentgenograms made at monthly intervals for six to twelve months. There were 53 patients with serial roentgenograms covering six to twelve month intervals for three years or more. Of these 53 patients, 9 were followed for six years, 5 for seven years, 9 for eight years, 3 for nine years, and 4 for ten years.

There is a group of 81 active cases with a combined record of serial roentgenograms and radiation treatment of one or more cycles. This group offers splendid information with respect to fibrosis and the clinical course of the cases, as well as material for estimating the probable incidence, degree, and rapidity of changes with different rates and intensities of irradiation. There was more time to evaluate any consideration of complicating pathologic entities with special reference to metastatic cancer. Of the 81 active cases, 29 over periods of one to ten years showed roentgenologic evidence of pulmonary fibrosis. Of these, 19 are clinically symptom-free, 10 having been observed for periods of five to ten years (Table 1).

Generally a negative lung twelve months after irradiation showed evidence of fibrosis, but in this series 7 cases of fibrosis oc-

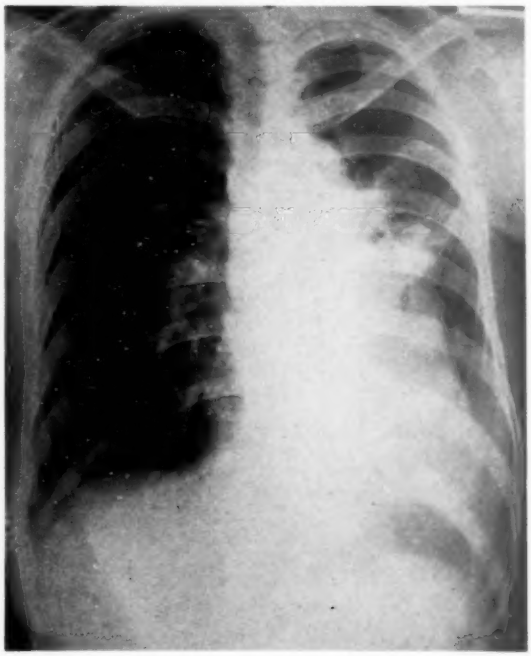

FIG. 19. F. S. March 28, 1940. Progressive involvement nine months later. Symptom-free April 11, 1940, except for marked persistent cough and chest soreness.

curred as late as eighteen months after the first cycle of irradiation, but 6 of the 7 cases received more than two cycles of approximately 4,000 to 6,000 r (air) to each of three or four skin portals.

Of 273 cases, 91 were given totals of 1,600 to 2,000 r (air) to each of three or four skin portals. Irradiation fibrosis developed in 11, or 12 per cent, of these cases, but of these 11, 9, or 81 per cent, were subsequently demonstrated to be complicated by metastatic cancer on the basis of roentgenographic involvement of the opposite lung and local recurrence and fatal termination together with some autopsy controls.

Table I

OF 81 ACTIVE CASES WITH SERIAL ROENTGENOGRAMS
DOSES 4×1400 to 1600 r (air)

Year	Cases Irradiation Fibrosis	Symptom-Free Cancer
1930	1	1
1931	1	1
1932	3	3
1933	1	1
1934	3	3
1935	1	1
1936	3	3
1937	5	2
1938	7	2
1939	4	2
	29	19

Of 273 cases, 182 received two or more cycles of irradiation within periods of four to eight months, and total doses of 3,000 to 6,000 r (air) to each of three or four skin portals. There was pulmonary fibrosis in 51, or 28 per cent, of these cases, but 44 of these (86 per cent) were later shown to be complicated by metastatic cancer to the lungs (Table II).

There were only 9, or 3.3 per cent, of 273 cases with roentgenographic evidence of pulmonary irradiation fibrosis without clinical or roentgenographic evidence in the subsequent course to indicate complicating factors of metastatic cancer to the lungs.

This experience seems to show that the majority of normal lungs will not show change from irradiation even with greater doses than were given in the cases developing fibrosis, and since fibrosis occurred in only 3.3 per cent of cases without evidence of metastatic cancer, this effect in these few cases was interpreted as possible vulnerability of the lung to irradiation as a result of underlying pathology in the nature of infection, arteriosclerosis, or possibly advanced age.

Of the 273 cases, 62, or 22 per cent, regardless of the number of cycles of irradiation, showed fibrosis, but 53, or 85 per cent, of these are shown subsequently to be complicated by metastatic cancer. It is obvious, therefore, that when one considers the possible effects of irradiation in the production of pulmonary fibrosis, consideration must be given to the character and degree of complicating pulmonary pathology. This study seems to indicate that roentgenographic evidence of irradiation fibrosis is compli-

Table II

SUMMARY OF INCIDENCE OF IRRADIATION FIBROSIS
(ACTIVE AND INACTIVE CASES) 41 AUTOPSIES

Number Cases	Doses	Roentgen Evidence Irradiation Fibrosis	Subsequent Proven Metastatic Cancer	Actual Cases Irradiation Fibrosis
91	4×2000 r (air) minus	11—12%	9—81%	2
182	4×4000 r (air) plus	51—28%	44—86%	7
273 total		62—22%	53—85%	9—3.3%

cated by metastatic carcinoma in 85 per cent of the cases.

SUMMARY

1. A clinical and roentgenologic study of irradiation pulmonary fibrosis was made to determine the degree and incidence according to the amount of treatment in cancer of the breast.

2. Pulmonary fibrosis with atelectasis was a permanent change and appeared within two to twelve months in variable degrees with radiation intensities of 1,600 to 2,000 r in one cycle, and with doses of 3,000 to 6,000 r in two or more cycles (air measurements) to each of three or four skin portals.

3. Of 273 cases, 62, or 22 per cent, showed roentgenographic evidence of fibrosis; but 53 of the 62 cases, or 85 per cent, were complicated by metastatic cancer as revealed clinically and roentgenographically and in 41 autopsied cases.

4. Identical procedures of irradiation showed pulmonary fibrosis in only 9, or 3.3 per cent, of 273 cases which were clinically free of cancer from three to ten years, which is the approximate incidence of irradiation fibrosis for so-called normal lungs.

5. This experience justifies the inference that when fibrosis of the lungs occurs after irradiation there is an underlying contributing factor which seems to be metastatic cancer (85 per cent of cases) or possible infection, arteriosclerosis, or advancing age (3.3 per cent of cases).

6. There was no resulting physical disability. Cough, pain, and dyspnea occurred to very slight degrees, but when these symptoms were marked and associated with failing health and strength, the eventual termination of the case was proved to be the result of metastatic cancer.

7. Roentgenologic determinations of irradiation fibrosis complicating and accentuating metastatic cancer or other possible factors of pathology are fraught with many complexities and inconsistencies, so that interpretations and conclusions may be controversial. Standards of evaluation are only approximate estimations in dealing with a clinical subject.

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DISCUSSION

DR. HARRIET C. MCINTOSH, New York City. I have been extremely interested in Dr. Widmann's paper. In the short time at my disposal, I want to make a few categorical statements which are more or less at variance with his conclusions.

Many of the papers that have been published on irradiation pneumonitis and irradiation fibrosis picture the disease as an uncertain and incalculable entity. It is shown attacking patients here and there, while many others having comparable doses of irradiation do not show it. Little if any account is taken of age, size of portals, amount of cross-firing into the lung, etc. Its very existence is doubted by some writers, or considered of questionable importance.

In a study which I did, partly alone and partly with Dr. Sophie Spitz, a group of 60 breast cases receiving irradiation were studied from every angle we could think of, in an effort to get at the root of the thing. It is of only limited value to say that in 234 cases so many showed irradiation fibrosis and so many did not. The interest lies in why they did, or did not.

Those 60 cases all had preoperative, pre-ir-

radiation films. They had films six weeks or two months following, and after that all those with positive findings had films every two months for six months; every three months for the next six months; and subsequently once a year as long as the study went on. In addition to that, every individual with positive findings was measured with a French curve, the form of their thoraces taken, and their depth doses into the lung computed.

This was done under the aegis of Dr. Quimby and it was done as accurately as is humanly possible for us to do it. Therefore, we have a more scientific basis, I think I have a right to say, as to what does and does not cause irradiation pneumonitis and irradiation fibrosis than either a study on bulk of cases, most of whom come in late stages as they naturally would with Dr. Widmann's group, or in such a situation as Warren and Spencer's reported in the June, 1940, number of the American Journal of Roentgenology and Radium Therapy. Here they took autopsies and worked backward, and their roentgen films were such as chance provided, but they weren't films logically spaced as I have mentioned.

This group of 60 cases was then analyzed first according to positive and negative chest findings, with degree of reaction graded I, II, III, IV. Second, patients were grouped according to age in three groups, under forty, forty to sixty, over sixty. They were then grouped according to amount of tissue dose, at certain determined points in the center of the treated lung, and the three sets of findings examined for correlations.

I believe definitely that the reaction is a quantitative one, modified by age and arteriosclerosis, and by two other factors I will speak of in a moment. Very large tissue doses cause lung reactions in all cases, resulting in some degree of pneumonitis. This may recede in a young or middle aged woman, and show nothing in a film a year later, or an autopsy two years later, and the existence of the reaction would be missed if films were not properly timed. Medium sized lung doses—and it should be noted we are not talking about surface doses—cause lung reaction in the aged, and in a certain proportion of the middle aged; rarely or transiently in those under forty. Low lung tissue doses produce reactions in some elderly persons, but fewer even of these than where higher doses are used.

The other modifications of this quantitative law are:

(1) Cross-firing into the mediastinum seems to produce greater effect, in changes seen in the roentgenograms and in morbidity, than similar amounts into peripheral lung.

(2) Very large portals, such as 20×20 cm., which not only increase the depth dose but also the cubic area of the vascular bed involved at one time.

I have just a few slides illustrating variation of age and lung tissue dose. The first shows the effect of a high lung dose in a young individual, aged thirty, taken three months after treatment. The next slide shows complete recovery six months after treatment.

The third slide shows the result of 5 threshold erythema doses into the lung in a middle aged woman.

The next two slides show the effect of 9 threshold erythema doses, one film made four months and the other nine months after treatment. This is an extreme case, and an extreme reaction, but this woman had no symptoms referable to the chest.

The next one is an old woman who had 6 threshold erythema doses into the middle of the lung and this is a four month film. The following slide is two and a half years later, showing residual fibrosis.

The next slide is a low dose, also in an old woman. It shows just as much reaction two months later as in the preceding case. She had 1½ threshold erythema doses, but the next slide shows how rapidly she cleared up. She is old, but she had a low dose.

Now the final slide illustrates a very interesting end point,—almost of laboratory accuracy. This was a woman of about fifty-three when she first came to me; she had a fibrocarcinoma in the right breast and three years later she had an adenocarcinoma in the left. She is the same woman and only three years didn't make much difference to her arteries. On the right side she had two cycles of the massive dose type three months apart; 750 r per field to five fields in the first series, and to three fields in the second series. Three years later the opposite side was given two cycles, 5 fields to the first, 3 fields to the second, at the rate of 400 r daily to one field, up to a total of 1,200 r per field. You will see a definite grade I irradiation fibrosis on the right and a clear lung on the left.

Dr. Widmann showed that the fractional

doses created more irradiation pneumonitis than the massive doses, and that is true, because we give higher total doses by the fractional method, but in this case we gave less because 750 r at a time is more intensive than 400 r three times around when you come to a given field every three or four days.

Out of 60 cases I had 36 cases with positive roentgen findings. The reason I knew they didn't have metastases is that we either had autopsies or they have lived for years. We have a clinic where you get very early cancer and that is why I can present this sort of material. Out of 36 positive pneumonitis cases, 15 were of the more severe degree, grade III and IV. There you see the symptoms,—cough, cough with dyspnea, dyspnea and pain. Five had bronchopneumonia, a single episode, with recovery.

The question of tangential irradiation scarcely arises because we are considering here lung doses and not tumor doses. I would like to say, however, that I use tangential irradiation where I consider it practical and effective.

DR. G. E. PFAHLER, Philadelphia. As you know, I have always been much interested in this question of the treatment of cancer of the breast and I have come to believe in the value of preoperative as well as the value of postoperative irradiation. If we do the preoperative treatment correctly, there is no occasion whatever for pneumonitis. There is no occasion for passing the rays through the lungs. If you do tangential treatment and send your rays through the breast from the inside and again from the outer side and just skim the chest wall, you have no reason for putting the rays through the lungs, and why should they develop pneumonitis? I don't get it at all!

I think Dr. Widmann's paper, which was very well prepared and demonstrated beyond any question, has shown in some of those cases that this evidence of disease in the lung was present even before, and I have shown even when Dr. Widmann was working with me, that we found these changes in the lungs and then under treatment tremendous progress in the disease for the reason that Dr. Widmann has given you.

Dr. Widmann shows final five year cures in 3 per cent without any evidence of metastasis. He concludes that they were not metastases because they lived five years. Why hasn't he just as good a right to conclude he cured those 3 per cent of cases?

Dr. Holfelder, reporting on about 36 cases of carcinoma of the lung, says he produced fibrosis in all of them, and so have I and so do you if you treat cancer of the lung successfully. You will produce fibrosis, and if you put enough radiation through the lungs, you will produce fibrosis, but in the preoperative or postoperative treatment of cancer of the breast this is not necessary.

We must all realize this,—that this fibrosis has a cumulative effect. It is not a matter of merely whether you give it in fractional doses or massive doses. You will produce a pneumonitis more quickly with massive doses in large quantity, but you can also produce it with small doses just as most of your degenerative effects on skin and subcutaneous tissue are due to the cumulative effect.

Let us keep the technique in mind by which these cases were treated and correct the technique. Then we will get results and will avoid these damages. You just can't turn these patients over to technicians and say, "Give two doses anteriorly" or "Give two doses posteriorly," or whatever it happens to be, and produce results and no damage. It takes careful anatomical knowledge to direct these rays and get them in the right place.

We must always keep in mind that there is danger of damage to healthy tissue. When the cancer is in the mediastinum, it doesn't matter whether you give irradiation or not.

Vol. 47, No. 1

CARCINOMA OF THE LOWER LIP

INTERVAL STATISTICAL SURVEY OF THE END-RESULTS IN ALL CASES TREATED AT THE BROOKLYN CANCER INSTITUTE, 1930 TO 1939 INCLUSIVE

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BROOKLYN, NEW YORK

IN THE decade between 1930 and 1939 inclusive 100 cases were admitted to the clinic or wards of the Brooklyn Cancer Institute with a clinical diagnosis of carcinoma of the lower lip. Two cases were omitted from further study as they had received extensive irradiation elsewhere and had been sent into the clinic only after local recurrence and glandular extension. Their condition was such that neither surgery nor further irradiation was considered feasible. Five cases were omitted due to inadequate pathological proof of their diagnosis. Nineteen cases were deleted because the follow-up traces these patients for less than six months. Such a short period is entirely inadequate to determine the success or failure of the treatment procedure.

There was only one female in the entire group; the balance, or 73, were males. The youngest patient was but thirty-two while the oldest had passed his eighty-sixth year, the average being sixty-two for the entire series.

ETIOLOGY

As would be expected, many of the men were pipe smokers and others smoked cigars and cigarettes. Unfortunately, the habits were not listed in all cases. It is estimated, however, that well over 90 per cent of the whole group were smokers. The charts showed that only the woman denied ever having smoked.

All but one case in the series had had blood Wassermann studies. Six had positive blood serology, only 3 of whom gave strongly positive reactions; the other 3 were on the borderline of 1 plus or doubtful. These laboratory studies would suggest an average of only a little over 3 per cent whose blood reaction indicated an active luetic process. It would appear that the presence of latent tertiary syphilis must be higher in this series than these tests would indicate. These serological studies would indicate that a syphilitic process is not an etiological factor in carcinoma of the lip.

The incidence of a single injury to the lip was also proportionately low. Only one man had been struck on the lip and had noted the nodule after the trauma; another patient remembered an insect bite at the site where the lesion later appeared.

Again, partly due to the nature of the clinic, many of the men were of the unskilled laboring group who probably had received much exposure to wind and sun. Many of these new growths were associated with extensive leukoplakic changes on the mucous membrane surface and atrophy and keratosis of the carmine surface. Most of the patients had dirty mouths with carious teeth and infected gums. The occlusal areas were often irregular, and any dentures were

TABLE I

Admission Ten Year Period in Brooklyn Cancer Institute		
Clinical Diagnosis of Carcinoma of Lower Lip		100
Omitted because no therapy was attempted	2	
Omitted because of insufficient pathological data	5	
Omitted because of insufficient follow-up	19	
Total Omissions		26
Total proved treated cases with six months or over follow-up		74

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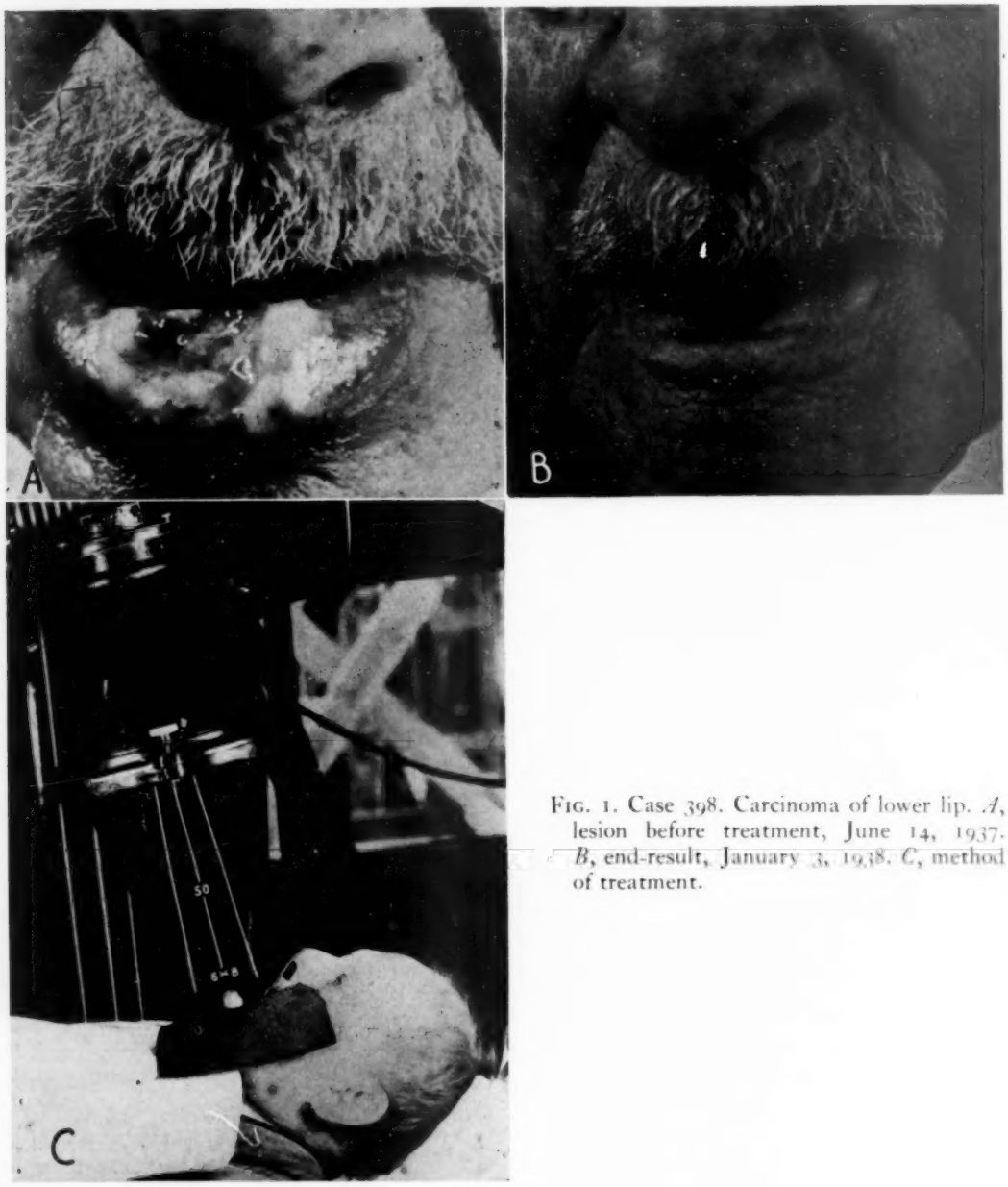

FIG. 1. Case 398. Carcinoma of lower lip. *A*, lesion before treatment, June 14, 1937. *B*, end-result, January 3, 1938. *C*, method of treatment.

poorly fitting so that the lip may often have been traumatized and irritated.

DURATION AND EXTENT

The lip is particularly sensitive and is so conspicuous that the earliest changes should be noticeable both to the patient and his intimates, yet the duration of the knowledge of the diseased condition in this series varied from three weeks to twenty years. The majority of individuals waited years rather than months before seeking medical advice. The average interval in all cases was eighteen and a half months. As would be expected from such a long growth period most of the lesions measured over 2 cm. in diameter and were definitely ulcerated when first seen.

Several patients had multiple areas of involvement, apparently developing on leu-

koplakic or keratotic changes in the epithelial surface. In at least one case two discrete and rather far separated lesions developed independently. Several men had involvement of over two-thirds of the lip surface when first seen. Only one case was observed to have a so-called contact lesion on the upper lip, a condition that is so commonly observed in carcinoma of the vulva.

Palpable submental, submaxillary or cervical lymphatic glands were present in 6 cases on first admission. An additional 14 cases, or over 15 per cent, are listed as having developed such palpable lymph nodes (carcinoma?) after treatment.

PATHOLOGY

All of the cases but one were grouped as squamous cell carcinoma. The exception to the rule was one basal cell lesion which occurred on the upper surface of the lip. On inspection there were no differences in the gross appearance of this lesion as compared with other squamous cell carcinomas. One lesion involved the lower lip at its external angle and there is some debate as to whether this carcinoma did not originate on the mucous membrane side of the cheek and should therefore be grouped with the cases of carcinoma of the buccal mucosa rather than lip.

TREATMENT

The cases have been listed in Table II according to treatment.

From our own personal experience and the experiences of many, as shown by numerous articles,[1,2,3,6] the lip lesion can be controlled by the following methods:

(1) *Surgically*—by radical excision. To succeed the surgeon must go far beyond the visible edges of the lesion and remove all of the carcinomatous tissue. This often results in mutilation, as in the production of the so-called "fish mouth" deformity, unless suitable plastic procedures are carried on to overcome this end-result.

(2) *Radiologically*—by massive doses. The application of roentgen rays or radium must again be such that sufficient radiation is introduced into the tissues to entirely destroy all of the tumor.

As the records show, most of these cases were treated by irradiation, partly due to the fact that many of these individuals could be handled in the out-patient department, thus saving the available beds for non-ambulatory cases, and partly due to the fact that many of the lesions were extensive and the immediate irradiation results appeared satisfactory.

(*A*) *Surgery*. Only one case was treated by surgery alone to the lip. The lesion was an extensive one; the surgery was unsuc-

Table II

	Total	Average Duration Follow-up	Developed Glandular Extension	Result	
				Success	Failure
Roentgen therapy to lip	31	2+ yr.	4	29	2
Radium mold to lip	9	2+ yr.	2	7	2
Interstitial radium to lip	11	1½ yr.	0	11	0
Surgery to lip	1	6 mo.	0	0	1
Roentgen therapy and surgery to lip	5	2+ yr.	1	4	1
Surgery and interstitial radium to lip	2	1 yr.	0	1	1
Radium mold and roentgen therapy to lip	2	1½ yr.	2	0	2
Interstitial radium and roentgen therapy to lip	11	2+ yr.	5	5	6
Radium mold and interstitial radium to lip	1	4½ yr.	0	1	0
Roentgen therapy, interstitial radium and surgery	1	3½ yr.	0	1	0
	74		14	59	15

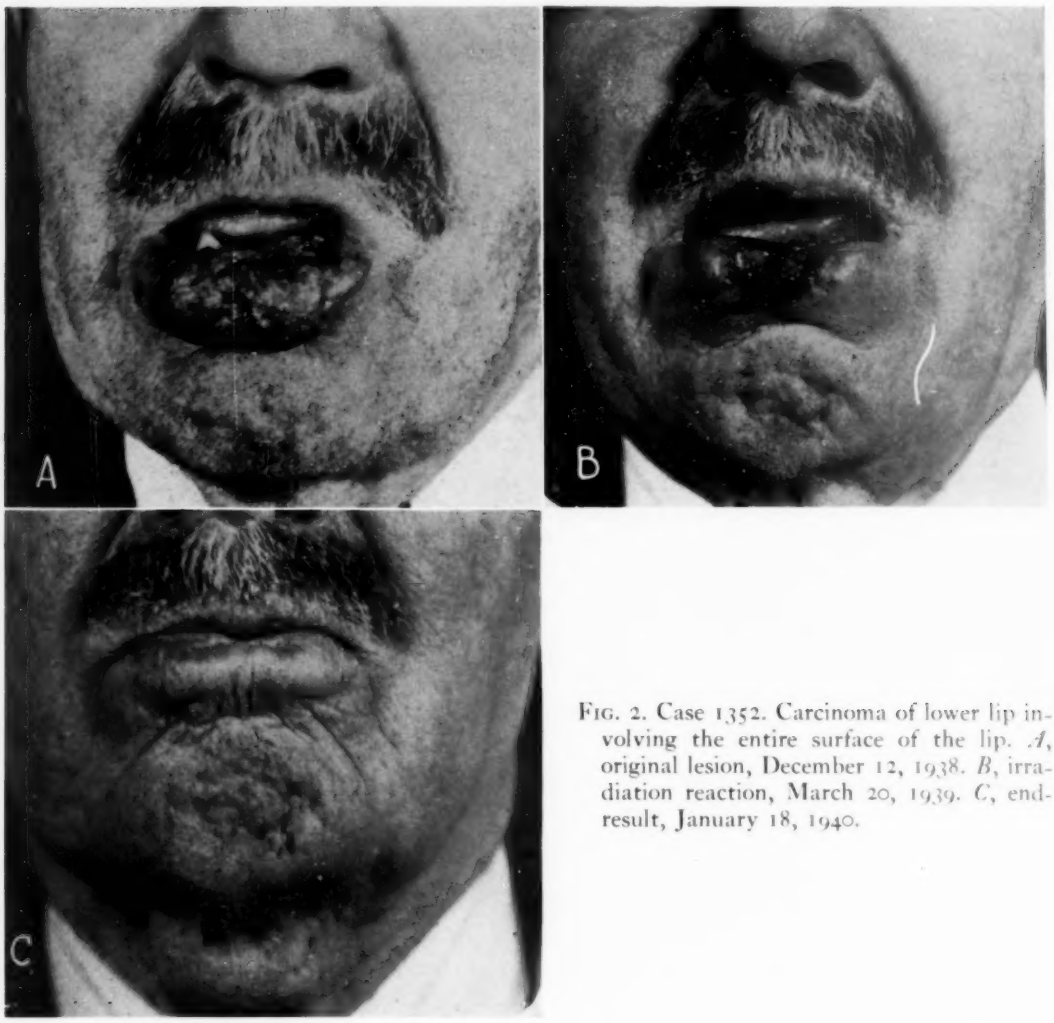

FIG. 2. Case 1352. Carcinoma of lower lip involving the entire surface of the lip. *A*, original lesion, December 12, 1938. *B*, irradiation reaction, March 20, 1939. *C*, end-result, January 18, 1940.

cessful and the patient died six months later from infection and spread of the carcinoma in the submaxillary triangle.

(*B*) *Combined Procedures.* Six cases were treated by surgery to the lip, which either preceded or followed roentgen therapy. Five of these have had a satisfactory end-result. All are being followed in the clinic, averaging two and a half years to date. One case in this group also had a small amount of interstitial radium. The single failure died of extension nine months after treatment. One of these patients had a double primary lesion. The surgeon agreed to excise the lesion on the right and the radiologist treated the one on the left. Both lesions have been successfully eradicated by this combined but rather unorthodox procedure and the patient has now been followed for over one year in the out-patient department.

Two cases were treated by combining interstitial radium with surgery. Here again one procedure followed the other because of recurrence and the change in method appeared to be the most feasible under the circumstances. One case was lost one and a half years after completion of treatment and is listed as satisfactory in that up to his last clinic visit no further evidence of the disease was noted. The second case was lost track of at the end

of six months. At his last attendance there was still evidence of carcinoma and the case is therefore grouped with the failures.

All of the other combined procedures to the lip were carried out because of incomplete destruction of the lesion by the original method. The results of such combined treatment would trend to show that incomplete eradication of the lesion by the original procedure definitely reduced that patient's chances of recovery. This is clearly seen in the end-results where interstitial radium was added after roentgen therapy, or vice versa. Here 5 cases out of 11 developed glandular involvement, only one of whom was successfully treated thereafter.

As a usual practice we would like to discourage combining surgery with irradiation in the treatment of the primary lesion. The surgeon is too apt to make a minimal excision, depending on the irradiation to destroy any residual cancer cells, and vice versa.

(*C*) *Roentgen Therapy*. The technique in the application of roentgen radiation has varied somewhat throughout the years. These changes resulted in an attempt to improve the appearance of the scar and in an effort to cure a larger number of patients. These changes have also been due to the added experience and knowledge of the members of the radiation therapy service.[4,5] In those cases of cancer of the lip treated before 1936, superficial therapy was employed, using 80 to 135 kv. with a half-value layer of 1 to 3.8 mm. of aluminum. The area was blocked to within 0.5 cm. of the lesion and a single dose of approximately

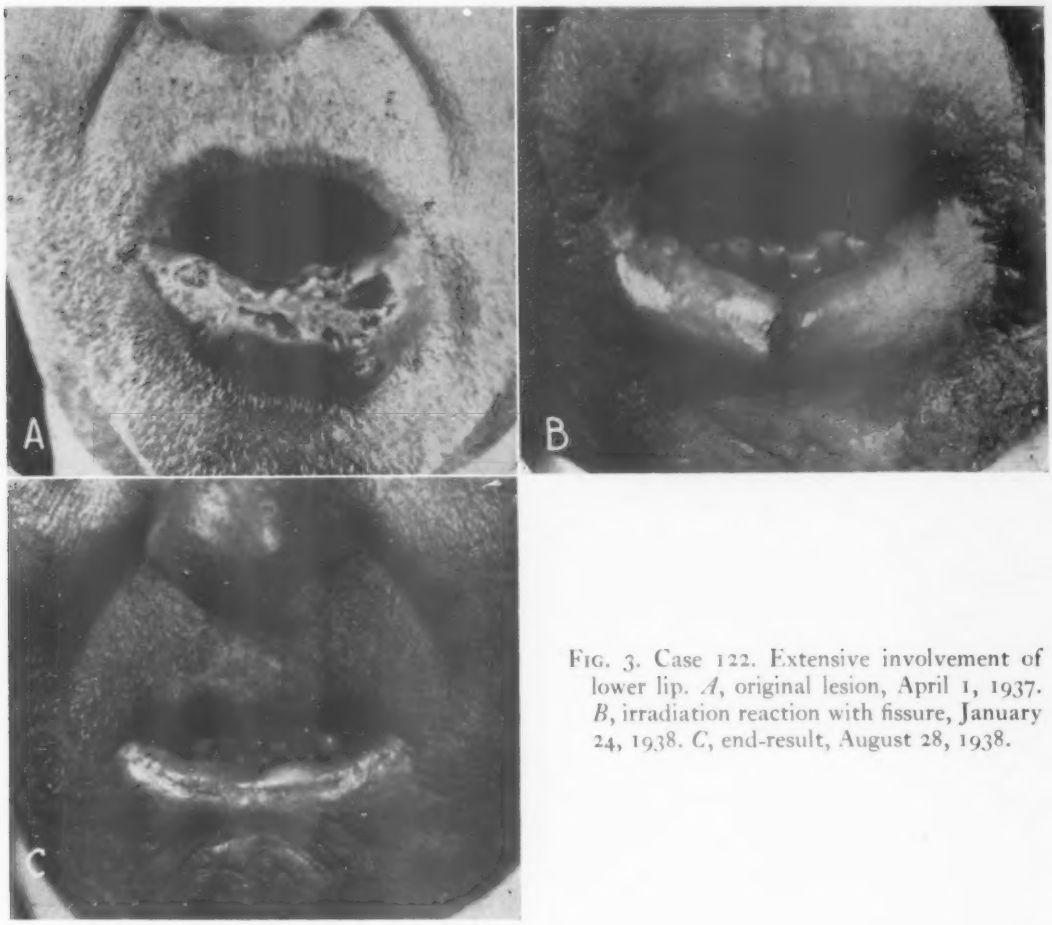

Fig. 3. Case 122. Extensive involvement of lower lip. *A*, original lesion, April 1, 1937. *B*, irradiation reaction with fissure, January 24, 1938. *C*, end-result, August 28, 1938.

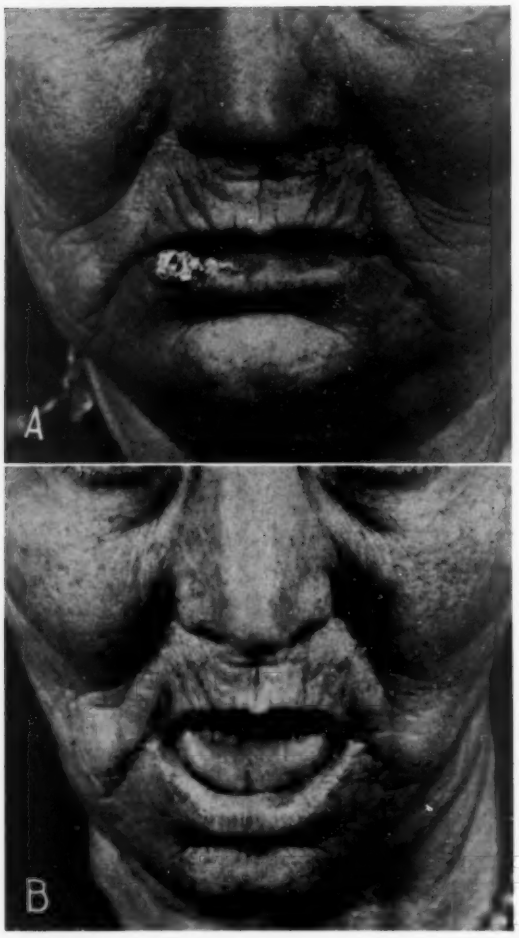

FIG. 4. Case 1773. Carcinoma of the lower lip, only female in the series. *A*, original lesion, June 20, 1939. *B*, end-result, October 6, 1939.

4,000 r, in air, delivered. After careful study of all failures, the total area was enlarged in that it was made a V-shape with about the same area irradiated as would be removed by adequate surgical dissection. The mouth structures were protected by placing adequate lead rubber within. The treatment was also divided into 8 to 12 daily fractionated doses. The technique now preferred is 200 kv., a half-value layer of 1.8 mm. Cu, 30 cm. skin target distance, giving 600 r, in air, daily. Recurrences have been noted when the total dose was reduced to 4,500 r or less. The irradiation reaction resulting from such a series of treatments is of course intense, but never attended by irradiation necrosis. The resulting scar is soft, pliable and contains minimal telangiectasia. Lesions which are so extensive that they include the entire surface of the lower lip have been successfully treated by this technique.

Of the 31 cases treated by roentgen therapy to the lip, 21 had the treatment confined to the lip as described. This group must, of necessity, not have had any extension of the process and all have had a satisfactory result to date. Their follow-up averages about two years. The other 10 cases had therapy to the submaxillary areas. In 7 the treatment consisted of further roentgen therapy. In 2 the neck was treated by dissection and one by the insertion of radon seeds. Two patients in this group had metastatic extension of the disease and were listed as failures: one of these was given roentgen therapy to the neck and the other had interstitial radium placed in the site of extension. There is no pathological proof that those survivals treated by external irradiation alone to the neck ever had carcinomatous extension.

FIG. 5. Case 8749. Carcinoma of lower lip; similar involvement of upper lip.

The proportionately large number of cases who have been carried along from six and a half years to six months after roentgen therapy to the local lesion only make it seem inadvisable to give routine therapy or do routine dissection of the submaxillary and submental areas before palpable masses can be demonstrated. In the first place, the surgeon or radiologist would again be tempted to do a minimum, insufficient to control actual extension of the carcinoma and still sufficient to affect the amount of subsequent irradiation or the character of the subsequent surgery which might be needed later. Add to this the complications that can follow irradiation, such as skin breakdown, irradiation osteitis and laryngeal edema, and the complications which can also follow such a technical surgical procedure, such as hemorrhage, infection and pneumonitis. It is also significant to note that of the 3 cases who were subjected to block dissection, only one had tissue removed in which the pathologist could identify carcinoma. All of the 3 cases had palpable glands in the neck before surgery was contemplated.

(*D*) *Radium Treatment.* Nine cases were treated with a radium mold to the lip. Here the attempt was made to cross fire the lesion by placing tubes on the buccal upper and external surfaces of the lip some 0.7

Fig. 6. Case 1742. Carcinoma at angle of the lower lip.

Fig. 7. Case 8888. Extensive carcinoma involving the entire lower lip. *A*, lesion October 29, 1936. *B*, end-result January 24, 1938.

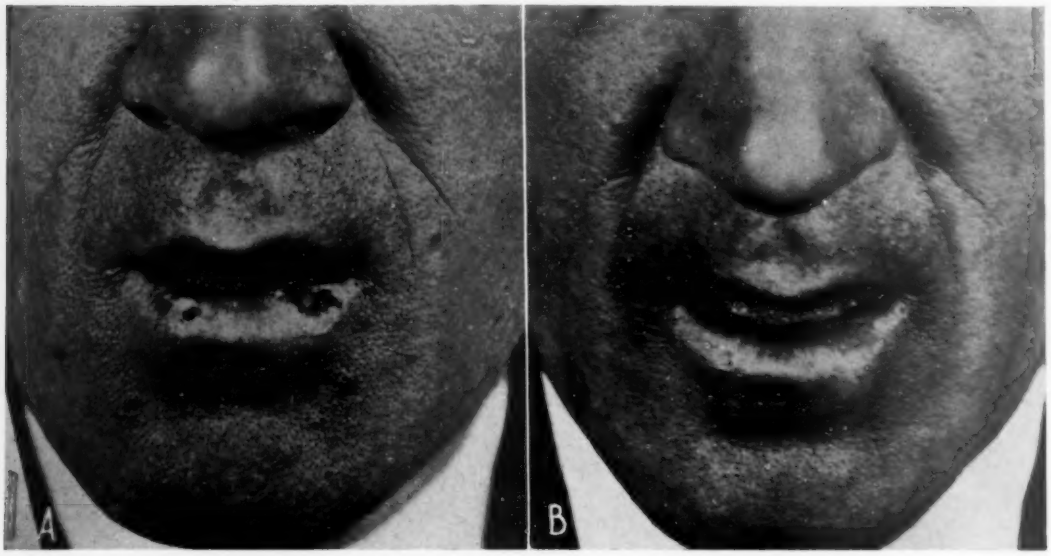

FIG. 8. Case 1452. Double primary carcinoma of the lower lip. *A*, lesion at right excised surgically; lesion at left treated by roentgen therapy, February 2, 1939. *B*, end-result May 11, 1939.

to 1 cm. off the surface, filtration 1 mm. platinum. Total dose of course varied with the extent of the lesion, being from 1,200 to 2,400 mg-hr. Two died as failures with further extension of the lesion, living about one and a half years after treatment. One died of an intercurrent disease three years after treatment. Four were lost track of two and a half years after treatment, at which time there was no evidence of recurrence or glandular extension. Two are still being followed in the clinic three years eight months and two and a half years after treatment. In each of these the lesion appears to be well controlled.

Eleven cases were treated by the insertion of radium needles or radon seeds in and about the lesion. The dose varied from 4 to 12 millicuries-destroyed. There was not a single failure in this group when not combined with some other method. One died three years after treatment with no evidence of extension. One case was lost to follow-up one and a half years after treatment. The average survival period to date is two years.

(*E*) *Treatment of Metastases.* Six cases were admitted with palpable glandular masses either in the submental area or the submaxillary triangle. The only one cured in this group was given roentgen therapy to the lip and this followed by radical dissection to the neck. Three of the others are known to have died about one year after therapy; one has been lost track of after six months of follow-up and one is still under observation one year two months after treatment. His condition is considered hopeless.

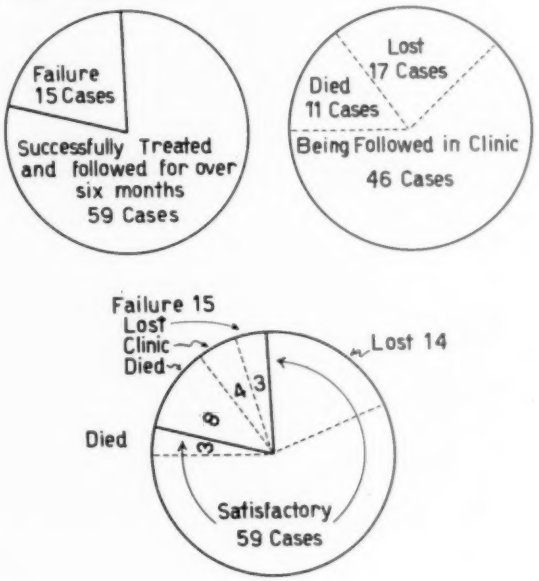

FIG. 9

As shown on Table II, 14 cases developed evidence of extension following the original therapy; only 4 of these were cured: one by treatment of the involved metastatic area with interstitial radon (a total of 30 millicuries-destroyed was given to an area 2+

Table III

Year	Case No.	Treatment to Lip	Treatment to Neck	History	Duration of Follow-up	Glands on Admission	Metastatic Spread	End-Result	Treatment Result
1930	3220	Radium mold	No	6 mo.	2½ yr.	No	Yes	Died	Failure
	3384	Surgery	Roentgen therapy	1 yr.	6 mo.	Yes	Yes	Died	Failure
1931	3489	Roentgen therapy Interstitial radium	No	3 yr.	2 yr.	No	No	Lost	Satisfactory
	3852	Roentgen therapy	Roentgen therapy	6 mo.	1½ yr.	No	No	Lost	Satisfactory
	3960	Radium mold	Roentgen therapy	1 yr. 3 mo.	1½ yr.	No	No	Lost	Satisfactory
	4003	Radium mold	Roentgen therapy	4 mo.	3 yr.	No	No	Lost	Satisfactory
	4024	Radium mold	Roentgen therapy	2 mo.	4 yr. 3 mo.	No	No	Lost	Satisfactory
1932	4083	Radon mold	Roentgen therapy	1 yr.	9 mo.	Yes	Yes	Died	Failure
	5332	Surgery and interstitial radon	No	3 wk.	1½ yr.	No	No	Lost	Satisfactory
	5508	Roentgen therapy	Roentgen therapy	2 mo.	6 mo.	No	No	Lost	Satisfactory
1933	5973	Interstitial radon	No	6 mo.	7 yr.	No	No	Clinic	Satisfactory
	6040	Roentgen therapy	Roentgen therapy	2 mo.	3 yr.	No	No	Lost	Satisfactory
	6085	Roentgen therapy	Roentgen therapy	3 yr.	3 yr.	No	No	Died	Satisfactory
	6251	Radium mold	No	6 mo.	1 yr. 6 mo.	No	No	Lost	Satisfactory
	6409	Roentgen therapy	Roentgen therapy	6 wk.	6½ yr.	No	No	Clinic	Satisfactory
	6475	Radium mold and roentgen therapy	Roentgen therapy	1½ mo.	6 mo.	No	Yes	Lost	Failure
	6668	Roentgen therapy	No	3 mo.	1 yr.	No	No	Lost	Satisfactory
1934	6704	Interstitial radon and roentgen therapy	Roentgen therapy and interstitial radium	2 mo.	3 yr.	No	Yes	Died	Failure
	6733	Roentgen therapy	Roentgen therapy	3 mo.	4 yr. 6 mo.	No	No	Lost	Satisfactory
	6921	Roentgen therapy	No	2 mo.	6 yr.	No	No	Clinic	Satisfactory
1935	7612	Interstitial radon and roentgen therapy	Roentgen therapy	2 yr.	2 yr.	No	Yes	Died	Failure
	8005	Roentgen therapy	No	7 mo.	1 yr.	No	No	Lost	Satisfactory
	8123	Radon mold and interstitial radon	No	1 yr.	4½ yr.	No	No	Clinic	Satisfactory
	8282	Roentgen therapy and interstitial radium	No	6 mo.	4 yr.	No	No	Clinic	Satisfactory
	8304	Roentgen therapy and interstitial radium	No	2 mo.	4 yr.	No	No	Clinic	Satisfactory
1936	8359	Surgery, interstitial radium and roentgen therapy	No	3 mo.	3 yr. 6 mo.	No	No	Clinic	Satisfactory
	8421	Radium mold	No	6 mo.	3 yr. 8 mo.	No	No	Clinic	Satisfactory
	8443	Radium mold	Interstitial radon and radium	4 mo.	3 yr. 9 mo.	No	Yes	Clinic	Satisfactory
	8447	Roentgen therapy	No	3 mo.	3 yr.	No	No	Lost	Satisfactory
	8510	Surgery and interstitial radium	Interstitial radium and roentgen therapy	8 mo.	6 mo.	Yes	Yes	Lost	Failure
	8523	Interstitial radium	Roentgen therapy	20 yr.	4 yr.	No	No	Clinic	Satisfactory
	8567	Interstitial radium	No	3 mo.	3 yr.	No	No	Died	Satisfactory
	8722	Surgery and roentgen therapy	No	6 mo.	3½ yr.	No	No	Clinic	Satisfactory
	8725	Roentgen therapy	Roentgen therapy	8 mo.	3 yr.	No	No	Died	Satisfactory
	8731	Interstitial radium and roentgen therapy	No	1 mo.	3 yr. 7 mo.	No	No	Clinic	Satisfactory
	8749	Interstitial radon and roentgen therapy	Interstitial radium and roentgen therapy	3 mo.	2 yr.	Yes	Yes	Died	Failure
	8759	Radium mold and roentgen therapy	No	3 wk.	3 yr.	No	Yes	Lost	Failure
	8770	Interstitial radium	No	1 yr.	3½ yr.	No	No	Clinic	Satisfactory
	8888	Roentgen therapy	No	4 mo.	3½ yr.	No	No	Clinic	Satisfactory

TABLE III—*Continued*

Year	Case No.	Treatment to Lip	Treatment to Neck	History	Duration of Follow-up	Glands on Admission	Metastatic Spread	End-result	Treatment Result
1937	47	Roentgen therapy	Surgery	10 mo.	2 yr. 3 mo.	Yes (block dissection)	Yes	Clinic	Satisfactory
	122	Roentgen therapy	No	6 mo.	2 yr. 6 mo.	No	No	Clinic	Satisfactory
	325	Roentgen therapy	No	3 mo.	2 yr. 9 mo.	No	No	Clinic	Satisfactory
	375	Interstitial radium and roentgen therapy	Surgery	8 mo.	2 yr. 4 mo.	No (block dissection)	Yes	Died	Satisfactory
	398	Roentgen therapy	Interstitial radium	10 yr.	1 yr.	No	Yes	Clinic	Failure
	546	Surgery and roentgen therapy	No	1 yr. 4 mo.	2 yr.	No	No	Clinic	Satisfactory
	558	Roentgen therapy	No	1 yr.	2 yr.	No	No	Clinic	Satisfactory
	595	Roentgen therapy	Surgery	1 yr.	2 yr.	No (block dissection)	Yes	Clinic	Satisfactory
	2036a	Radium mold	No	6 mo.	2 yr. 6 mo.	No	No	Clinic	Satisfactory
1938	674	Roentgen therapy	No	3½ yr.	1 yr. 10 mo	No	No	Clinic	Satisfactory
	831	Interstitial radium	No	1 yr.	2 yr.	No	No	Clinic	Satisfactory
	861	Interstitial radium	No	1½ yr.	2 yr.	No	No	Clinic	Satisfactory
	907	Roentgen therapy	No	3 mo.	1 yr. 6 mo.	No	No	Clinic	Satisfactory
	936	Interstitial radium	No	2 yr.	1 yr. 10 mo.	No	No	Clinic	Satisfactory
	945	Interstitial radium	No	8 mo.	1 yr. 6 mo.	No	No	Lost	Satisfactory
	1035	Interstitial radium and roentgen therapy	No	6 mo.	1 yr.	No	Yes	Clinic	Failure
	1112	Roentgen therapy	No	4 mo.	1 yr.	No	No	Clinic	Satisfactory
	1246	Interstitial radium and roentgen therapy	No	5 wk.	1 yr. 2 mo	Yes	Yes	Clinic	Failure
	1352	Roentgen therapy	No	2 mo.	1 yr.	No	No	Clinic	Satisfactory
	1380	Surgery and roentgen therapy	No	6 mo.	9 mo.	No	Yes	Died	Failure
1939	1411	Roentgen therapy	No	6 mo.	1 yr.	No	No	Clinic	Satisfactory
	1452	Surgery and roentgen therapy	No	7½ yr.	1 yr.	No	No	Clinic	Satisfactory
	1565	Roentgen therapy	No	6 mo.	1 yr.	No	No	Clinic	Satisfactory
	1648	Roentgen therapy	No	5 yr.	1 yr.	No	No	Clinic	Satisfactory
	1741	Surgery and roentgen therapy	No	3 mo.	9 mo.	No	No	Clinic	Satisfactory
	1742	Interstitial radium and roentgen therapy	Interstitial radium and roentgen therapy	4 mo.	10 mo.	No	Yes	Clinic	Failure
	1773	Roentgen therapy	No	1 yr.	10 mo.	No	No	Clinic	Satisfactory
	1850	Roentgen therapy	No	7 wk.	9 mo.	No	No	Clinic	Satisfactory
	1852	Roentgen therapy	Roentgen therapy	5 mo.	9 mo.	No	Yes	Clinic	Failure
	1895	Interstitial radium	No	7 mo.	6 mo.	No	No	Clinic	Satisfactory
	1912	Interstitial radium	No	3 yr.	6 mo.	No	No	Clinic	Satisfactory
	1940	Roentgen therapy	No	6 mo.	6 mo.	No	No	Clinic	Satisfactory
	1975	Interstitial radium	No	9 mo.	7 mo.	No	No	Clinic	Satisfactory
	1992	Roentgen therapy	No	1½ wk.	6 mo.	No	No	Clinic	Satisfactory
	2003	Roentgen therapy	No	10 wk.	6 mo.	No	No	Clinic	Satisfactory

cm. in diameter); the other 3 were treated by surgical dissection. The cases that were not controlled were treated by roentgen irradiation or interstitial radium to the metastatic areas. From these results and checking the experiences of others, we believe that external irradiation alone is insufficient to control these extensions, as not enough radiation can be delivered into the depth without danger of producing necrosis in the overlying skin, and therefore large doses of interstitial radium must be added to any external irradiation. When surgery is attempted, it should also be radical even to removal of a portion of the mandible, as the growth is apt to involve the periosteum or bone in both the submental and submaxillary zones.

IMPORTANCE OF FOLLOW-UP

In any attempt to evaluate treatment results, emphasis must be laid on the ability of the social service department to keep in proper touch with all patients. Such an effort is now being made at the Brooklyn Cancer Institute. All patients are given a

return date which is noted by the social service division. If this date goes by unheeded, the social service worker sends a letter requesting the patient to return. If this fails, the worker then makes a home visit. Unfortunately, prior to October, 1936, only half time of one worker was delegated to the Brooklyn Cancer Institute and thus she was unable to keep in contact with all patients, which explains the large number of patients lost track of in the earlier years.

SUMMARY OF ALL CASES (TABLE III)

In Table III the case numbers are included so that a final report of this group can be easily prepared at the end of another five years. The end-result is given under three headings: (1) Died, (2) Lost, and those still under observation are filed under (3) Clinic. The treatment end-result is given under two divisions: (1) Satisfactory, and (2) Failure. The result was deemed satisfactory if followed in the clinic for over six months without evidence of extension. Certain cases are known to have died of intercurrent disease—heart disease, tuberculosis, etc.—and who showed no evidence of recurrence or spread of the carcinoma and are therefore listed as a satisfactory end-result though known to be dead. Failure, of course, indicates presence of local or metastatic spread of the cancer.

In the whole group 15 cases are known to have been failures in that the cancer was not controlled. Eleven of these are known to have died. Seventeen patients have been lost track of—mostly in the earlier years. These are listed as to end-result according to evidence of any lesion in the last clinic record. The remainder, or 46 patients, are still being followed through the clinic.

Of the 11 cases known to be dead, 3 are known to have died of some intercurrent disease. The lip lesion was healed and there was no evidence of extension of the lesion to the cervical lymphatics at the time of death. Eight cases are known to have developed further extension to the submental, submaxillary region or cervical lymphatics before death. Many of these had carcinoma and osteomyelitis present in the mandible, a most formidable complication.

Fifty-nine cases have therefore been treated successfully. These cases have been followed for six and a half years to six months after the treatment, with an average follow-up of over two years.

SUMMARY

(1) Seventy-four cases of proved carcinoma of the lower lip have been followed at the Brooklyn Cancer Institute from six months to six and a half years following therapy: 59 of these are listed as successfully treated and 15 as failures.

(2) Surgery, radium or roentgen therapy to the local lesion may be equally efficient in producing a cure.

(3) Treatment of the submental and submaxillary areas should not be routinely carried out unless there is evidence of extension.

(4) External irradiation is insufficient to control glandular extension in itself, but may be successful if combined with interstitial radium therapy.

(5) If the local lesion is controlled, block dissection of the cervical lymphatics appears to offer the greatest hope of cure.

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RESULTS OF CONSERVATIVE TREATMENT IN CERTAIN CEREBRAL GLIOMAS*

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FOR the past five years we have treated most of our malignant cerebral gliomas by a combination of surgery and irradiation. From our own experience and the work of others we are convinced that the conservative treatment of such gliomas offers the patient the best chance of a fairly comfortable and useful, though short, life.

There are at present two schools of thought regarding the treatment of cerebral gliomas. One believes that they should be radically removed. The exponent of attempted radical removal virtually ignores the high mortality rate of operation and the crippling after-effects. The literature reports the total extirpation of an entire cerebral hemisphere, even of the left hemisphere in right-handed persons. This type of radical surgery, to quote Dr. Percival Bailey, results in a purely vegetative life for the survivor.

Bailey† in a recent paper describes the surgeon of the second school as one who attempts to estimate the operability of the patient, the size and extension of the tumor, and also its location. This is of importance in determining whether the surgeon intervenes radically, partially, palliatively, or abstains entirely. If this point of view is followed the number of operations will be less, the operative mortality will be a great deal lower, and the defects provoked by operating fewer. The treatment of cerebral gliomas is therefore not a purely radiation problem.

We concur with this philosophy of the second or more conservative school. Perhaps a brief review of the history behind these shifting and sometimes divergent viewpoints is in order.

Until the beginning of the Golden Age of Neurosurgery, in the early years of this century, tumors of the brain were rarely recognized and almost never operated upon. The peculiar specialized technique necessary for successful attack upon them had not been developed. The occasional patient on whom a correct diagnosis had been made fell into the hands of the general surgeon, who, if conscientious, accepted him reluctantly and temporized, hoping for the blessed intervention of death. The bolder and more reckless surgeons sometimes attempted operation with results so often unfortunate that the diagnosis "brain tumor," became synonymous with hopelessness and futility of therapy—a feeling not entirely eradicated from the general medical profession even today. Almost until 1910, the operative mortality of brain tumor, even including simple decompression, was about 50 per cent. Three or four years ago, the Society of Neurological Surgeons celebrated the 50th anniversary of the first removal of a simple lesion, with survival of the patient.

Shortly after 1900 Harvey Cushing went to Baltimore as resident at Johns Hopkins under the great Halsted. Halsted's meticulous technique fascinated him and he began applying it and modifying it to the special problems of surgery of the brain, to which he shortly confined himself. Despite Cushing's magnificent determination and courage, and his superlative natural skill, the grim record of his many failures in his first ten years is a testimonial to the almost insuperable difficulties he had to overcome. He emerged triumphant in the end, however, and the fundamentals of his methods are today universal.

With the conquering of surgical obstacles, the matter of the histopathological

† Bailey, P. Indications for surgical treatment of intracranial tumor. *South. Surgeon*, 1940, 9, 539–551.

* Read at the Forty-first Annual Meeting, American Roentgen Ray Society, Boston, Mass., Oct. 1–4, 1940.

differentiation had to be taken in hand. The glioma as a pathological entity had been recognized, but the many subdivisions with their varying local characteristics, and the marked differences between them in the life expectancies of the patients who harbored them had to be clarified. Surgeons, therefore, felt obligated to "verify" by actual removal of tumor tissue with subsequent microscopic examination, the lesions in all patients upon whom they operated. In deep tumors, or in those involving essential physiological areas, this often meant considerable mutilation for purely scientific purposes, with resultant enhancement of operative mortality and postoperative morbidity. It was basic work which had to be done and it culminated in Bailey and Cushing's classification of gliomas in 1926 with estimation of the life expectancy of each type, and in Cushing's monumental series of 2,000 cases, published on his retirement in 1932.

As a result of this twenty-five year development in the study of the true nature of gliomas of the brain and their response to varying modes of surgical attack, it became evident that they all had one thing in common—an inevitable tendency to recurrence, sooner or later.

The two schools of thought mentioned at the outset of our paper are therefore explained. The first or indiscriminately radical one, encouraged perhaps by the old urge to "verify" all cases, often sacrifices mortality and morbidity prospects in order to effect a maximal removal of all tumors. The second, to which we belong, feels that anything short of hopeless radicalism, like hemispherectomy, will fail to prevent recurrence and believes that each case should be treated on its merits. Many times it is better to return a relatively normal earning person to society after a short and comparatively inexpensive hospitalization, even those whose recurrence interval may be short, than to indulge in an operative tour de force and produce an aphasic or hemiplegic individual whose survival period, at best, is but little longer.

The roentgen treatment of brain lesions is not new, and the amount of irradiation the brain will tolerate has been quite well established. Children will tolerate less irradiation than adults. Bailey reports that 4,000 roentgens is about the maximum tolerance dose for children.

Davidoff, *et al.*,* report the effects of radiation applied to the brain and spinal cord of monkeys. Four thousand roentgens or more to the cerebral hemisphere were followed immediately by paralysis of the contralateral limbs. They report the death of 7 of the monkeys irradiated. Massive doses caused marked changes in the glia and nerve tissues, but the blood vessel changes were slight in degree. The size of the dose and the time interval seemed to determine the degree of histological changes.

Nessa† describes his technique and concludes that, regardless of the controversies about the value of roentgen therapy in the treatment of brain tumors, there are cases in which remarkable responses are obtained.

From our experience we believe the brain will tolerate relatively large doses of roentgen rays. It seems that large intensive series of roentgen treatments are more apt to cause permanent changes in the normal surrounding brain than smaller doses over a longer period. That changes do occur in the brain is admitted by most radiologists. Serious results, in fact death, may follow large doses of roentgen rays applied to the head of a patient with a brain tumor if no decompression has been performed, the death probably being due to edema and increased pressure.

In our own series we had one fatality following large amounts of roentgen rays given in a short period of time. The effects of roentgen rays on the brain are illustrated by 2 brief case reports.

A patient with a spongioblastoma irradiated

* Davidoff, L. M., Dyke, C. G., Elsberg, C. A., and Tarlov, I. M. Effect of radiation applied directly to the brain and spinal cord; experimental investigations on Macacus rhesus monkeys. *Radiology*, 1938, *31*, 451–463.

† Nessa, C. B. Effect of treatment of brain tumors with roentgen rays; review of University Hospital cases. *Radiology*, 1938, *31*, 670–677.

in September, 1936, was given 15,558 roentgens over a period of three years. Most of the radiation was administered during the first year. Five separate fields were irradiated. Improvement was rapid following the first series of treatment, and continued until July, 1939. Although the patient said she felt well, and asked to be allowed to return to work, she had much difficulty in talking, in controlling head movements, and lacked judgment. Neurological examination by Dr. Mackay revealed no evidence of the original symptoms. He attributed her neurological findings to brain atrophy which he believed due to the irradiation. The application of the roentgen rays to this patient was intensive and quite general.

Another patient was operated upon in January, 1938, for a right frontal lobe glioma. The radiation given was 18,822 r in eight series between January 14, 1938 and March 21, 1940. At each series the areas through which the treatments were administered were intentionally small and well localized. At the present time the patient is in an excellent state of health and has been teaching school for the past year and a half.

It is not an uncommon experience to have patients thus react differently to roentgen irradiation. Over a period of years it has been conclusively demonstrated that patients with malignant lesions respond differently to roentgen rays, even of the same quality and same intensity. Probably the careful localization and small areas treated played an important part in the limited amount of reaction experienced by the second patient. As reported, the first patient received a generalized irradiation to the brain through large areas and over a short period of time. Undoubtedly, however, the susceptibility of the brain to the radiation varies with different individuals.

All 23 patients in the series have been operated upon. If at the operation, by means of palpation and needling of the brain, soft disintegrated material is met with in the depth of the hemisphere, and other factors have indicated the probable malignant gliomatous nature of the lesion, no attempt at histological verification is made. The removal of tissue for histological study in many cases leads to the destruction of a vital portion of the brain. Consequently some of our cases lack microscopic confirmation. All have been left with decompressions.

On the third postoperative day roentgen therapy is instituted. Inasmuch as many of these patients are unconscious great care must be exercised in their treatment. If possible large doses of vitamin B_1 are given the patient, usually about 9,000 international units daily. Thiamin chloride in large doses seems to control the nausea and patients feel generally improved.

Inasmuch as we are including in this series only cerebral gliomas, the roentgen procedure will be described as it applies to tumors in this area. For example, a patient with a right temporal lobe tumor will receive 4,500 r through five portals. Usually one area is treated a day and only in rare cases do we give two treatments. It would be hazardous to attempt two treatments daily in the absence of a large decompression and it would also be unwise where there is great bulging at the decompression due to increased intracranial pressure. Two hundred kilovolts with filters of 1 mm. Cu plus 1 mm. Al are used in most of our work. Only in rare cases have we used 500 kv. Following the series, usually of two weeks' duration, the patient is discharged and instructed to return after a period of one month. A second series is given after a lapse of two months. The patient is examined every month thereafter. If there is steady improvement and no return of symptoms, such as headaches, no further treatment is given. Our experience has convinced us that it is not possible to cure these patients by any form of treatment. We are only attempting to prolong their lives and make them comfortable. Should there be a return of symptoms—and there often is after six or eight months—another series of treatment is administered.

The question now arises whether the improvement these patients experience is due to decompression, roentgen irradiation, or a combination of the two. If the patient's improvement is due entirely to decompres-

sion there should be a definite abatement of symptoms and neurological findings in no longer than a week after the operation. On the other hand, if the symptoms and findings continue, and the patient is comatose for a week or more, the chances are that there will be no further improvement or benefit derived from the decompression. Then the patient is referred to the Department of Radiology for consultation and treatment. Roentgen irradiation is then instituted. If after the administration of a series of treatments the patient regains his consciousness and becomes mentally alert, it is difficult to deny that the improvement is due to the irradiation.

Large cerebral hernias often accompany brain tumors, especially if the glioma is large and the pressure greatly increased. The hernia will continue to increase in size as long as the tumor continues to grow. The decompression only allows more room for the expansion of the tumor in the brain. In this way the symptoms may to a certain degree be delayed and minimized. It is not unusual following irradiation to see a marked diminution, in fact disappearance, of the brain hernia. Accompanying the diminution is a marked improvement in the patient's general condition. In the resistant and unfavorable patient the hernia becomes larger and continues to grow even after large doses of roentgen radiation. Also after the patient has had a series of roentgen treatments and shows improvement, the improvement continues only as long as the decompression remains flat. With an elevation of the flap there is usually a return of symptoms. The irradiation is of value only as long as it has a tendency to return this flap to the normal contour of the skull.

We are therefore not claiming that our method of procedure, namely conservative surgery plus irradiation, cures these patients. We do believe it increases their period of comfort and usefulness. The majority of our patients die within a period of two years. Our only justification for presenting this paper is to show the temporary restoration to a comparative normal which often follows roentgen treatment. A patient's life can usually be prolonged for some two years in comparative comfort and with control of his faculties by the use of conservative surgery followed by irradiation.

DISCUSSION

Dr. Gilbert Horrax, Boston. There are so many points to discuss about the paper by Dr. Jenkinson and Dr. Oldberg that I hardly know where to begin. As we all know, roentgen irradiation has very definite effects on certain types of brain tumors and we can eliminate, of course, from the discussion the medulloblastomas of the cerebellum, and the cystic gliomas. The cystic gliomas, I believe, no one tries to irradiate. We know they can be cured by emptying the cyst and taking out the nodule of the tumor. The medulloblastomas are known to be radiosensitive.

In a general way, I belong to the school which favors radical surgery in all types of glioma with various exceptions because there is no general rule. It was Dr. Cushing's teaching and I have followed it so far. I may change from year to year, but so far it has seemed wiser to me to be very radical. I do not mean that we do hemispherectomies or exceedingly damaging operations of that character except in rare instances, because the resulting clinical state of the patient does not warrant such a procedure.

Some years ago I had occasion to look up the question of the microscopic aspects of roentgen treatment on the gliomas of the brain, and looked up 50 cases, partly of Dr. Cushing's series and partly of my own, at that time, patients who had had their tumors verified at operation and subsequently had been given irradiation, and then at a second operation again the tumor verified microscopically, so that one could tell, or one could examine the histological sections and see what changes had taken place.

I went over those sections very carefully with the pathologist and, with one or two exceptions, I believe, of these 50 cases of glioblastoma, solid astrocytoma, and oligodendroglioma, in only one of these cases could we be sure there was any effect of roentgen treatment. We went over the clinical history of these patients and there again one could attribute any possible improvement that had taken place to

the operation itself or to the decompression which was left. I think we are still at a loss to know how much irradiation does accomplish in these patients.

As Dr. Jenkinson said, it is quite true of these cases of Dr. Oldberg's, they have not all been verified. I think one cannot draw too definite conclusions when this is the case, and he did not try to draw them. We must be dealing with tumors of which we know the nature before we can talk about what effect irradiation, or anything else may have.

With this in mind, I did look up some of our recent cases, and let me say now that with the radical operation we try to take out all the tumor we can see at the time of operation. If that involves the right frontal lobe, or the right temporal lobe, or even in some cases the occipital lobes, we do a lobectomy so as to give the patient a maximum removal of the tumor, and then close the dura, thus doing what Mackenzie has called internal decompression. By that means we feel we get the maximum benefit for the patient.

I admit that the radical operation has a mortality higher, without much question, than the non-radical, but I don't think that is a serious thing with malignant tumors. With benign tumors we find a little over 12 per cent mortality but with malignant tumors it is two or three times this figure.

Up to last June I collected 18 tumors of the glioma group, 8 astrocytomas, 5 oligodendrogliomas, and 5 glioblastomas. In 6 of these patients, 3 of the oligodendrogliomas and 3 of the glioblastomas and astrocytomas, one patient only was given roentgen treatment. All these 18 patients lived from one to nine years; 10 of them from five to nine years, and 8 from one to three years, and those who lived longest were the patients with astrocytomas and some with the oligodendrogliomas. My own feeling is that we have to take the economic situation and all other kinds of things into consideration, but my personal belief is that to do the radical operation at the time of exposure of the tumor gives the maximum benefit. So far as I can see, from the work I have done on the microscopic examination of these brain tumors before and after roentgen treatment, roentgen irradiation does not affect the glioblastomas, the oligodendrogliomas, or the astrocytomas.

DR. C. G. DYKE, New York. At the Neurological Institute we feel very much the same as Dr. Jenkinson and Dr. Oldberg do about the use of moderate doses of radiation in the management of the glioblastomas. These tumors have proved to be highly malignant and it has been found that between 5,000 and 10,000 r, measured in air, and given within a period of three to six months is about the best dosage. This statement is based upon the study made of a number of patients who had a glioblastoma multiforme and who were irradiated. Those patients who received less than 5,000 r or more than 10,000 r had a very short postoperative survival period.

What this study really needs is a base line and the best source to obtain this is from the group of cases in the Harvey Cushing collection. There we have a series of 2,000 patients, about half of whom had gliomas. The glioblastoma multiforme cases should be divided into two groups; those that did not receive irradiation and secondly, those that did receive irradiation and how much. The length of the postoperative survival should be given for each group. At present there are no statistics available for postoperative survival of these patients.

I should like to mention here that the work of the group at Philadelphia has been very important in the matter of determining whether irradiation has any value in the treatment of gliomas, and particularly the work of Drs. Pendergrass, Alpers and the late Dr. Pancoast.

It is our experience, in the treatment of a number of monkeys and of patients who have come to autopsy, that it is the white matter that particularly feels the effects of irradiation. The cortical neuroblasts remain relatively intact, but the glia cells show the effects immediately. The blood vessels are injured only later and the effects on the tumor, I believe, are directly on the glia cells themselves and not indirectly due to injury of the vessels.

DR. JENKINSON (closing). I have very little further to offer as Dr. Horrax has been very generous in his discussion. I am sure that Dr. Horrax could have been very critical as there are a number of weak points in our paper, such as the lack of histological confirmation in a number of our cases. The histological confirmation of tumors is not a radiation problem and it rests with the surgeon. The surgeon likewise must make up his mind at the time of operation whether he deems it advisable to traumatize the brain extensively in order to procure a specimen. If the tumor is deep and it is hazardous

to try to obtain a section, Dr. Oldberg resorts to the needle. As I have stated above this is a surgical problem and it rests with the surgeon to determine what the best procedure would be.

An inquiry was made about our irradiation technique. It usually consists of the following treatment: the patient is given about 4,500 r, measured in air, usually through five portals of entry. Heavy filter is used, equivalent to 2 mm. Cu. The amount of treatment and the technique vary in different cases, oftentimes depending upon the information we receive from Dr. Oldberg. The location and the size of the tumor are usually given consideration.

The question of the amount of roentgen radiation that the brain will tolerate has been discussed in the paper and by many other authors. Anything we might add would be based on our clinical observations rather than histological studies.

Dr. Dyke brought up one point which fits in nicely with one of our patients who has probably lived longer than any other we have treated. We have treated her for over a period of three years and have been guided by her eyegrounds and neurological findings. From time to time there has been some recurrence of symptoms, but these subside after a series of roentgen treatment. At the present time she is alert and carries on her duties as a school teacher. As far as we can tell clinically there is no evidence of any brain atrophy.

IRRADIATION SICKNESS*

A CRITICAL STUDY

By S. S. STEINBERG, M.D.
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WITHIN the past decade, irradiation sickness has become a problem of considerable magnitude, and consequently many methods for the prophylaxis and treatment of this complication have appeared in the medical literature. However, the majority of the material published has been described by the authors as preliminary findings generally based on 30 or 40 cases (I have found no follow-up report). These initial studies have served an excellent purpose since they have stimulated work in this field, and have given us new remedies with which to treat this refractory condition.

While these records have been enlightening, they represent mainly the authors' own procedure, failing to furnish comparison with other methods. A comparative study of the commonly used drugs or physical means for the alleviation of this distressing syndrome would be of paramount interest. A criterion or yardstick for measuring the relative efficiency of the various forms of treatment would give a working basis for further research in this field. One of the salient points of this paper is to propose such a standard. But before discussing this standard, I believe it is important to review some of the major aspects of irradiation sickness.

1. *Individuality of Patients.* Irradiation sickness varies in each individual patient. It varies both as to the time of its onset and in its severity. It may appear when the patient has received 200, 2,000 or 10,000 r (measured in air), or it may not appear at all.

2. *Condition of the Patient.* If a marked secondary anemia is present or if the patient is debilitated, it is almost impossible to give an adequate dose of roentgen rays without producing one or more of the symptoms of this malady.

3. *Area Irradiated.* Treatment over the epigastrium or over the small bowel is more apt to cause digestive disturbances than treatment over such areas as the neck or the extremities.

4. *Type of Tissue Treated.* When large radiosensitive tumors are broken down, nausea and vomiting are prone to occur.

5. *Size of the Portal of Entry of the Roentgen-Ray Beam.* The susceptibility of the patient to irradiation sickness varies directly with the size of the portal. Distressing symptoms occur more frequently with the use of a 20×20 cm. cone than when a 10×10 cm. cone is utilized.

6. *Daily Dose.* The probability of the appearance of roentgen-ray sickness in a given patient varies directly as the size of the daily dose. Many patients will tolerate a daily dose of 100 or 200 r, but will become sick if they are given 400 r in the same interval.

It is my opinion that the six points listed above are in accord with the views of most therapists. It represents my own experience and the impressions of various men with whom I have been in contact. These points are contributing factors and are not to be confused with the various theories about the origin of irradiation sickness which I shall discuss next: (1) ozone in the treatment room; (2) various psychic factors; (3) disorders associated with protein metabolism; (4) effects on the sympathetic nervous system; (5) the effect of positrons in the therapy room.

(1) *Considering the effect of ozone*, we can, for the main part, disregard it. Many of us are using valve tube rectifiers, with the transformers some distance from the treat-

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ment room. The treatment room itself is entirely free from ozone. It is readily understandable that in the old-fashioned treatment room with its mechanical rectifiers ozone and the oxides of nitrogen did play an important rôle in the production of roentgen-ray sickness.

(2) *Reviewing the various psychic factors*, it is evident that many patients are upset by the massive appearance of a roentgen-ray machine and by their natural fright for electrical appliances; but against psychic phenomena being a major cause, we have the following two factors: that (*a*) in so many cases irradiation sickness appears after the patient has become familiar with the machine, and (*b*) that a 200 kv. machine is not infrequently used in treating small areas (2 or 3 cm. in diameter), and in these cases irradiation sickness does not occur.

(3) *Abnormal protein metabolism* certainly is an important factor. Experience has taught us that when a large radiosensitive tumor is broken down, irradiation sickness is prone to occur; and unquestionably treatment over the epigastrium or over the small bowel produces considerable change in the protein metabolism of the individual. I feel it is only necessary to refer the reader to the intensive work done by Warren and Whipple and their associates to convince him of the importance of this factor.

(4) *The Effect on the Sympathetic Nervous System.* Undoubtedly, when the abdominal contents are irradiated, the sympathetic parasympathetic balance is affected to some degree. Although the German authors discuss this theory at length, actually very little is known about the physiology and radiobiology of this system.

(5) A more recent theory has been advanced on the basis of the effect of *positrons in the deep therapy room.* The use of a mask or of a metallic screen which has been grounded to the deep therapy machine has been advocated and very good results reported. But if positrons are the etiology of irradiation sickness, why does treatment over the epigastrium cause symptoms of this disease whereas no symptoms may appear when the same dosage is applied to the chest?

With the foregoing in mind, I shall discuss the various remedies suggested and attempt to evaluate the systems most commonly used. My studies are confined primarily to the effects of (1) slow technique; (2) liver extract; (3) vitamin B_1;(4) metallic screen, and (5) high sodium chloride intake.

(1) It has been known for some time, that by the use of protraction, large total doses can be given without producing excessive epithelitis or irradiation sickness. The disadvantages of prolonged treatment are the strain on the patient, and the progressive loss of efficacy of the roentgen rays as the irradiation is extended into the refractory cycle of the tumor.

(2) While the use of liver extract is of recent origin, it has many adherents. Dietel[16] in 1933 reported 15 cases treated with the oral extract. Webster[67] in 1934 treated 10 patients in a similar fashion. Other investigators have used the intramuscular preparations.

(3) Thiamine chloride (vitamin B_1) has its advocates. In discussing the use of this medication, care should be taken to mention (*a*) the daily dose employed, and (*b*) whether or not this drug has been used orally or intramuscularly. In a series of cases reported below, 2,000 units (6.6 mg.) were given daily. In a second series, daily doses of 16,667 units (50 mg.) were employed. In my experience, thiamine chloride had little specific effect in either the prophylaxis or the treatment of irradiation sickness.

(4) The use of the metallic screen grounded to a deep therapy machine has not been successful in my experience, although I must admit that it was used in cases of a very severe type where large radiosensitive tumors existed in the epigastrium.

(5) High sodium chloride intake (10 gm. daily) suggested itself to me because so many of the symptoms of irradiation sickness are similar to those of adrenal cortex

deficiency. I felt that the use of saline would catalyze any adrenal cortical extract stored in the internal organs. A review of the literature shows that numerous other authors had previously used high sodium chloride intake. Schlagintweit and Sielmann[52] reported, from Munich, the use of high sodium chloride intake by mouth, by rectum, and by vein. Mahnert and Zacher[36] reported the use of 25 per cent glucose or hypertonic solutions of sodium chloride. Their results were encouraging. Cameron and McMillan,[9] working at the University of Manitoba, confirmed these results, with the use of sodium chloride as a physiologic solution given subcutaneously or intravenously. Cori and Pucher[11] reported the accidental finding of marked chloride retention, often amounting to over 70 per cent in cases subjected to deep roentgen therapy. In 10 successive cases, I was unable to verify the presence of chloride retention. Three blood chloride determinations were done on each patient without any consistent change being noted in the blood chloride findings.

Other groups have sought for the etiology of this disease along more diversified channels. Lange[34] believed that the alkali reserve was lowered. Accordingly, he treated his patients with sodium bicarbonate and reported good results. However, Golden[21] was unable to verify Lange's[34] results. Narat[43] believed that the condition is caused by the diminution of the function of the adrenals. He based this idea on experiments performed on rabbits.

Some groups feel that the condition is brought about by alteration of the sympathetic parasympathetic balance. This theory was advanced by Crevoisier.[12] Tuffier[62] reported relief with the use of adrenalin. Von Pannewitz[48] used lobelin in 150 cases with good results.

Another group favor the use of cholesterin or its derivatives. Burgheim[7,8] reported 100 cases treated with colsil. Schneider[54] and Waegner[63] also reported good results with the use of colsil.

Viosterol was advocated by Smith[61] in 1929. His results appeared convincing. However, Ford,[19] working at the Mayo Clinic, was unable to verify his findings. Her laboratory animals showed no improvement by the use of viosterol. My own results with viosterol have never been convincing.

Other substances that have been used are: corpus luteum by Lafferty and Phillips;[33] nautisan, a derivative of chlorobutanol in 122 cases by Wittkowsky;[69] cardiazol and ephedrine by Hug;[27] morphine sulphate, calcium chloride, and calcium lactate by Doub.[17]

Some authors have discussed the use of nembutal in the prevention and treatment of roentgen sickness. When using nembutal, one should bear in mind the reports on the development of porphins by combination of barbital derivatives and irradiation. Most probably, nembutal is effective in a high-strung type of individual, by decreasing the patient's nervousness; but it is my feeling that too many patients are already using the barbital derivatives, and that their use should not be encouraged. Obviously, the effect of such a drug is palliative rather than curative.

An analysis of 103 consecutive cases is listed in Table 1 to illustrate the relative efficiency of the methods which I have used either prophylactically or therapeutically.

The percentage of efficiency is an arbitrary figure based on the five cardinal symptoms of irradiation sickness and on the ratio of the dose (in roentgens) actually given to the dose scheduled. Percentages were allotted to the various symptoms in accordance with their relative importance, as follows:

(1) Lassitude	15 per cent
(2) Nausea	15 per cent
(3) Anorexia	15 per cent
(4) Vomiting	25 per cent
(5) Exhaustion	30 per cent

The efficiency of any remedy in a given case was determined in the following manner. If a patient developed lassitude (15 per cent) and nausea (15 per cent) a total of 30 per cent was subtracted, leaving a relative efficiency of 70 per cent. If the sched-

TABLE I

IRRADIATION SICKNESS

Case No.	Diagnosis	Area Irradiated	Size of Portal cm.	Total Dose		Drug or Method	Percentage Effective	
				Scheduled	Given		Prophylactic	Therapeutic
1	Cancer of esophagus	Epigastrium	10×15	6,000 r	10,000 r	Saline	—	90
2	Cancer of stomach	Epigastrium	10×15	6,000 r	9,800 r	Saline	75	—
3	Cancer of esophagus	Epigastrium	10×15	6,000 r	9,800 r	Saline	70	—
4	Cancer of esophagus	Epigastrium	10×15	6,000 r	8,600 r	Saline	60	—
5	Cancer of cervix Schm. II	Pelvis	20×20	4,000 r	3,600 r	Saline	—	80
6	Cancer of cervix Schm. III	Pelvis	20×20	4,000 r	4,000 r	Saline	—	90
7	Cancer of cervix Schm. III	Pelvis	20×20	4,000 r	2,000 r	Saline	—	60
8	Cancer of cervix Schm. IV	Pelvis	20×20	4,000 r	2,400 r	Saline	36	—
9	Cancer of cervix Schm. IV	Pelvis	20×20	4,000 r	3,200 r	Saline	68	—
10	Cancer of cervix Schm. II	Pelvis	20×20	4,000 r	4,000 r	Saline	100	—
11	Cancer of cervix Schm. III	Pelvis	20×20	4,000 r	3,600 r	Saline	81	—
12	Adenocarcinoma of uterus	Pelvis	20×20	4,000 r	4,000 r	Saline	90	—
13	Cancer of cervix	Pelvis	20×20	4,000 r	4,000 r	Saline	90	—
14	Cystadenoma of ovaries	Pelvis	20×20	4,000 r	3,200 r	Saline	68	—
15	Cancer of cervix Schm. IV	Pelvis	20×20	4,000 r	2,800 r	Saline	42	—
16	Cancer of cervix Schm. IV	Pelvis	20×20	4,000 r	1,000 r	Saline	15	—
17	Cancer of cervix	Pelvis	20×20	4,000 r	4,000 r	Saline	100	—
18	Cancer of prostate	Pelvis	10×15	6,000 r	4,000 r	Saline	—	40
19	Cancer of prostate	Pelvis	10×15	6,000 r	6,000 r	Saline	—	100
20	Cancer of prostate	Pelvis	10×15	6,000 r	6,000 r	Saline	100	—
21	Metastases teratoma testis	Epigastrium	15×15	4,000 r	4,000 r	Saline	100	—
22	Urogenital ridge tumor	Epigastrium	15×15	4,000 r	3,600 r	Saline	—	64
23	Osteogenic sarcoma	Arm	20×20	4,000 r	4,400 r	Saline	—	30
24	Cervical metastases	Neck	10×15	2,000 r	2,000 r	Saline	100	—
25	Cancer of breast	Chest	15×15	4,000 r	4,000 r	Saline	100	—
26	Brain tumor	Head	10×15	10,000 r	9,000 r	Saline	90	—
27	Cancer of tonsil	Neck	10×15	4,000 r	5,000 r	Saline	100	—
28	Myelogenous leukemia	Spleen	15×15	600 r	600 r	Saline	80	—
29	Cancer of tongue	Face	10×15	4,000 r	3,600 r	Saline	80	—
30	Hodgkin's disease	Neck Mediastinum	15×15	1,600 r	1,600 r	Saline	100	—
31	Metrorrhagia	Pelvis	15×15	1,600 r	1,600 r	Saline	100	—
32	Cancer of tongue	Neck	15×15	4,000 r	4,000 r	Oral liver extract	100	—
33	Hodgkin's disease	Mediastinum	15×15	3,900 r	3,900 r	Oral liver extract	100	—

TABLE I—*Continued*

Case No.	Diagnosis	Area Irradiated	Size of Portal cm.	Total Dose		Drug or Method	Percentage Effective	
				Scheduled	Given		Prophylactic	Therapeutic
34	Metastases from cancer of breast	Neck, chest, pelvis	15×15	6,100 r	6,100 r	Oral liver extract	80	—
35	Metrorrhagia	Pelvis	15×15	3,000 r	7,000 r	Oral liver extract	80	—
36	Cancer of breast postoperative	Chest	15×15	4,000 r	4,000 r	Oral liver extract	90	—
37	Fibroid of uterus	Pelvis	15×15	3,600 r	3,600 r	Oral liver extract	75	—
38	Pituitary adenoma	Head	15×15	4,000 r	4,500 r	Oral liver extract	60	—
39	Giant cell tumor	Upper femur	15×15	3,000 r	3,000 r	Oral liver extract	60	—
40	Postoperative hypernephroma	Abdomen	15×15	3,000 r	2,800 r	Oral liver extract	80	—
41	Hodgkin's disease	Mediastinum	15×15	2,000 r	2,500 r	Oral liver extract	60	—
42	Postoperative cancer of breast	Chest	15×15	4,000 r	4,000 r	Oral liver extract	85	—
43	Vaginal metastases	Pelvis	15×15	4,000 r	4,300 r	Oral liver extract	50	—
44	Cancer prostate; bone metastasis	Pelvis	15×15	4,000 r	6,400 r	Oral liver extract	60	—
45	Myelogenous leukemia	Spleen	15×15	1,000 r	1,400 r	Oral liver extract	60	—
46	Metrorrhagia	Pelvis	15×15	3,000 r	5,000 r	Oral liver extract	85	—
47	Cancer of uterus	Pelvis	15×15	4,000 r	1,700 r	Oral liver extract	10	—
48	Cancer of cervix with metastasis	Pelvis	15×15	4,000 r	800 r	Oral liver extract	—	—
49	Fibroid	Pelvis	15×15	3,000 r	3,000 r	Oral liver extract	55	—
50	Cancer of cervix	Pelvis	15×15	10,000 r	9,400 r	Oral liver extract	65	—
51	Fibroid	Pelvis	15×15	3,600 r	3,600 r	Oral liver extract	85	—
52	Metastatic submaxillary node	Neck	15×15	4,000 r	4,200 r	Oral liver extract	70	—
53	Cancer of breast postoperative	Chest	15×15	5,200 r	5,200 r	Oral liver extract	100	—
54	Fibroid	Pelvis	15×15	2,700 r	2,700 r	Oral liver extract	83	—
55	Hodgkin's disease	Abdomen	15×15	600 r	700 r	Oral liver extract	70	—
56	Cancer of prostate	Pelvis	15×15	8,000 r	7,400 r	Oral liver extract	76	—
57	Cancer of cervix	Pelvis	15×15	8,000 r	7,200 r	Oral liver extract	63	—
58	Hodgkin's disease	Chest Abdomen	15×15	2,100 r 400 r	400 r 400 r	Oral liver extract	85	—
59	Postoperative cancer of breast	Chest	15×15	4,000 r	5,400 r	Liver extract	100	—
60	Postoperative cancer of breast	Chest	15×15	2,000 r	2,000 r	Injection liver extract	100	—
61	Cancer of cervix Schm. IV	Pelvis	15×15	8,000 r	2,200 r	Liver extract injection	12	—
62	Malignant lymphoma	Chest	15×15	1,400 r	1,400 r	Injection liver extract	55	—
63	Cancer of stomach, postoperative nodes	Abdomen	15×15	3,000 r	3,000 r	Injection liver extract	55	—
64	Cancer of breast postoperative	Chest Abdomen	15×15	5,000 r 1,400 r	5,000 r 1,400 r	Injection liver extract	100	—
65	Hodgkin's disease	Chest	15×15	2,000 r	2,200 r	Injection liver extract	70	—

Table I—*Continued*

Case No.	Diagnosis	Area Irradiated	Size of Portal cm.	Total Dose		Drug or Method	Percentage Effective	
				Scheduled	Given		Prophylactic	Therapeutic
66	Postoperative cancer of breast	Chest	15×15	4,000 r	6,000 r	Injection liver extract	90	—
67	Pelvic bone metastases	Pelvis	15×15	4,000 r	5,900 r	Slow technique	85	—
68	Postoperative cancer of breast	Chest	15×15	4,000 r	5,000 r	Slow technique	100	—
69	Bone metastasis sternum	Chest	15×15	2,000 r	2,000 r	Slow technique	100	—
70	Cancer of maxilla	Jaw	15×15	4,000 r	3,800 r	Slow technique	95	—
71	Tongue	Jaw	15×15	4,000 r	6,400 r	Slow technique	19	95
72	Cancer of prostate metastasis	Pelvis	15×15	3,700 r	3,700 r	Slow technique	85	—
73	Cancer of lip with metastasis to cervical nodes	Neck	15×15	4,000 r	4,400 r	Slow technique	85	—
74	Bronchiogenic cancer	Chest	15×15	4,000 r	2,800 r	Slow technique	28	—
75	Cancer of breast postoperative	Chest	15×15	5,000 r	5,000 r	Slow technique	100	—
76	Metrorrhagia	Pelvis	15×15	2,600 r	2,600 r	Slow technique	70	—
77	Gout feet	Feet	15×15	2,000 r	2,000 r	Slow technique	100	—
78	Mixed tumor parotid	Parotid	15×15	3,000 r	3,000 r	Slow technique	100	—
79	Cancer of cervix Schm. IV	Pelvis	15×15	10,000 r	10,000 r	Injection liver Slow technique	30 90	—
80	Metrorrhagia	Pelvis	15×15	2,000 r	2,300 r	Injection liver Slow technique	30 85	—
81	Fibroid	Pelvis	15×15	3,000 r	4,200 r	Injection liver Slow technique	30 85	—
82	Cancer of cervix	Pelvis	15×15	10,000 r	9,800 r	Injection liver Slow technique	55 85	—
83	Fibroid	Pelvis	15×15	2,000 r	2,000 r	Injection liver Slow technique	55 100	—
84	Fibroid	Pelvis	15×15	3,000 r	5,800 r	Injection liver Slow technique	55 75	—
85	Fibroid	Pelvis	15×15	2,000 r	2,000 r	Injection liver Slow technique	55 100	—
86	Fibroid	Pelvis	15×15	2,000 r	2,000 r	Injection liver Slow technique	55 100	—
87	Postoperative cancer of breast	Chest	15×15	4,000 r	7,000 r	Injection liver Slow technique	30 90	—
88	Postoperative cancer of breast	Chest	15×15	4,000 r	7,000 r	Injection liver Slow technique	60 90	—
89	Cancer of breast preoperative	Breast	15×15	10,000 r	13,300 r	Injection liver Slow technique	60 95	—
90	Metrorrhagia	Pelvis	15×15	2,000 r	4,400 r	Vitamin B	60	—
91	Herpes ophth.	Head	15×15	600 r	600 r	Vitamin B_1 2,000 r daily	55	—
92	Herpes ophth.	Head	15×15	600 r	600 r	Vitamin B_1 2,000 r daily	40	—
93	Herpes chest	Chest	15×15	400 r	400 r	Vitamin B_1 16,667	55	—

TABLE I—*Continued*

Case No.	Diagnosis	Area Irradiated	Size of Portal cm.	Total Dose		Drug of Method	Percentage Effective	
				Scheduled	Given		Prophylactic	Therapeutic
94	Herpes chest	Chest	15×15	1,400 r	1,400 r	Vitamin B_1 16,667	55	—
95	Sciatica	Hips	15×15	400 r	400 r	Vitamin B_1 16,667	55	—
96	Tic doloreux	Face	15×15	400 r	400 r	Vitamin B_1 16,667	55	—
97	Tic doloreux	Face	15×15	300 r	300 r	Vitamin B_1 16,607	40	—
98	Metastasis	Epigastrium Mediastinum	15×15	—	9,400 r	Screen	0	
						Vitamin B_1	0	
						Injection liver extract	30	—
						Slow technique	60	
99	Hodgkin's disease	Neck Mediastinum	15×15	—	4,100 r	Vitamin B_1	30	
						Vitamin E	30	
						Slow technique	60	—
						Screen	0	
100	Hodgkin's disease	Mediastinum	15×15	—	900 r	Injection liver extract	0	
						Screen	0	—
						Slow technique	60	
101	Chronic hemorrhagic cystitis	Pelvis	15×15	2,000 r	2,200 r	Fe sulphate	85	—
102	Metrorrhagia	Pelvis	15×15	1,000 r	1,100 r	—	100	—
103	Postoperative cancer of breast	Chest Ovaries	15×15	4,000 r	6,500 r 1,800 r	—	100	—

uled dose was 4,000 r, and the patient received 3,600 r, then only 3,600/4,000 or 9/10 of the total dose was given. Now, 9/10 of 70 per cent is 63 per cent. In other words, the remedy would be 63 per cent effective in the given case. Although this is an arbitrary calculation, it gives a means for comparing the various methods in use. On this basis, the following comparative standing has been computed:

1. Slow technique (200 r or less daily), 26 cases, 82 per cent effective.
2. Saline therapy (10 gm. daily), 31 cases, 77 per cent effective.
3. Liver extract (oral), 27 cases, 70 per cent effective.
4. Liver extract (intramuscular), 20 cases, 51 per cent effective.
5. Vitamin B_1, 10 cases, 44 per cent effective.
6. Metallic screen, 3 cases, 0 per cent effective.

From these figures, it is apparent that the most effective manner in which to avoid irradiation sickness is to give small daily doses. A corollary to this statement would be that the portal of entry of the roentgen-ray beam should not be over 15×15 cm. Saline therapy and liver extract by mouth are almost equally effective. Intramuscular liver extract appears to be of less value. Vitamin B_1 was not very effective. The metallic screen was of no value in my experience. My patients felt that it aggravated their discomfort.

CONCLUSIONS

1. Many substances and physical measures for the treatment of irradiation sickness have been advocated.

2. No method appears to be specific. Most of them are beneficial either by improving the general state of the patient or

by the psychic effect of the added attention which the patient receives from his physician.

3. Many patients who develop roentgen-ray sickness are relieved of their symptoms if treatment is suspended for several days.

4. Large total doses may be administered without the use of any drug or physical remedy if the rate of irradiation does not exceed 200 roentgens daily.

5. It is recommended that any report dealing with drugs or other means for combating irradiation sickness should take into consideration the following six factors:

(1) The condition of the patient.
(2) The area or site of irradiation.
(3) The size of the portal of entry of the roentgen-ray beam.
(4) The number of roentgens given daily.
(5) The ratio of the scheduled dose to the dose that is actually given.
(6) That many patients do not develop irradiation sickness even though they are given large daily and large total doses. The last point is of particular interest when one attempts to evaluate the prophylactic effect of the various remedies.

6. Proctitis and cystitis are reactions of the mucosa of these organs. These reactions appear to be analogous to the erythematous changes in the skin.

7. The effect of roentgen rays on the adrenal glands either by their direct action or by the action of the protein products which are formed secondarily as result of irradiation, appears to be a fertile field for study.

8. Criteria for the evaluation of remedies for irradiation sickness are suggested.

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A DISCUSSION ON SURVEYS OF THE CHEST

WITH COMMENTS ON THE 14 BY 17 INCH FILM AS USED IN THE CANADIAN ARMY*

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THERE would probably be no difference of opinion regarding the statement that the most effective single agency for finding tuberculosis carriers is the roentgen examination. In civilian life the value of this method is limited entirely by the extent to which it is used, and the ideal would be reached if the entire population could be examined at intervals from childhood on into adult life. As a public health measure such an application of the method is highly desirable, but while one may hope it will ultimately be realized it is clear that this will take much time.

When the selection of recruits for military service is considered this method of examination is not only desirable—it is essential, not only to ensure that carriers of tuberculosis capable of infecting others will be rigidly excluded and that men enlisted will not break down under service due to previously unsuspected pulmonary lesions, but also to protect the country from enormous expenses in hospitalization and pensions resulting from either of the above.

Since these statements are generally accepted, the object of the present discussion, as I understand it, is not to debate the *fact* of the value of the roentgen-ray method but to endeavor to reach a conclusion as to the relative merits of the several methods available for survey purposes to decide which we are prepared to endorse.

Other things being equal, it would seem that the following requirements might be regarded as essential for any method which could be accepted as adequate for the purpose:

1. Availability—It must be as universally available as possible.
2. Economy —It must be economical.
3. Accuracy —It must be accurate.

1. Availability. In Canada the decision to use the single 14×17 in. film for the examination of recruits was reached largely because of the fact that it was almost universally available. Men applying for acceptance as recruits are at their own expense until they have been accepted into the army. This includes travelling expense to the recruiting center and living expenses until they are accepted or rejected. Hence it is desirable that satisfactory roentgen-ray facilities be present at every recruiting center in order that this part of the examination may be carried out with the least possible delay.

It is well known that in both Canada and the United States facilities exist in practically every community where recruiting is carried on by which roentgen examinations may be secured. In some cases this may be in a small hospital where there is no roentgenologist competent to render an authoritative report, in which case the men can be held and the films sent to the district consultant radiologist. This opinion is available within a very short time. If it is favorable the man has lost no time and, if not, he is discharged as unfit immediately.

The second reason why the 14×17 in. film method was adopted in Canada is a corollary to the above. Not only were these facilities everywhere available—they were available immediately upon the declaration that Canada was at war so that almost as soon as recruiting started the medical examination included a roentgen-ray survey including a single 14×17 in. film.

The question which should now be con-

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sidered is whether this method has proved to be satisfactory or whether there is a better one available. It may as well be admitted at the outset that this question in the final analysis becomes almost entirely a financial question. The Army is anxious to ensure itself against the physical breakdown of men in its ranks, the treasury officials against the payment of pensions after the war. Both are anxious to accomplish this with the least primary cost, and the method which involves the least expense is very likely to be the one chosen.

2. Economy and Convenience. In Canada the civilian radiologists agreed to donate their professional services without remuneration, and as a result the fee paid for these surveys was $2.00, for which the radiologist supplied the film, developed it and supplied the filing envelope. Report forms were provided by the Government. At the present time very few civilian radiologists are made use of, since there are now many military camps or hospitals adequately equipped with facilities for this work. For the first period of recruiting, however, for which we have figures, the cost to the country was $2.00 per examination.

As this subject is studied it becomes more and more evident that the great difference between chest surveys in civilian and in military life is that in civilian cases the largest item of cost is finding the tuberculosis carrier. In the Province of Ontario we have a very active and efficient tuberculosis prevention department which has calculated that it costs approximately $500.00 to *find* each case of tuberculosis. After that it costs the Province for treatment roughly $1,000.00 for each minimal case, $3,000.00 for each moderately advanced, and about $5,000.00 for each advanced case or an average of $4,000 to $5,000 for each case of proven tuberculosis. These figures are approximate and would vary with different countries. But in the case of an enlisted soldier who develops tuberculosis the expense is tremendously increased since it includes not only hospitalization as in the civilian but also a pension for life and usually a living allowance for his wife and family. In Canada following the previous war, this amounted to an average of about $25,000 per case.

At this point consideration should be given to the recognition of non-tuberculous pulmonary infections which is a subject to which far too little attention has been paid. When mass surveys of this kind are spoken of the majority of physicians think only in terms of tuberculosis and it is usually true that most public health officials are not greatly interested in non-tuberculous cases since they are not contagious and therefore, like the poor unfortunate victims of cancer, the state does not feel much responsibility for them—their trouble is their own affair so long as they are not a source of danger to others. But, here again, the military case differs widely from the civilian. In the army non-tuberculous infections can be quite as crippling in their effects upon the efficiency of personnel as tuberculosis, and it is rather startling to many to discover that the cost for hospitalization and pensions is from four to six times that for tuberculosis.

During the present war the figures supplied to me from the Director General's office indicate that during one period of recruiting 328,325 men were examined by the single 14×17 in. film method and of these 5,273, or 1.6 per cent, were rejected as a result of information directly disclosed by this examination, of which 3,076 were tuberculous and 1,088 non-tuberculous pulmonary disease. The balance were cardiac or other conditions. Using the same costs as resulted from the experience of the last war it can easily be seen that this investment of some $600,000 for the roentgen survey has resulted in a saving to the country of something over $20,000,000.00. Actually, as we know, the present costs will be higher than previously. But even at the minimum figure it may be calculated that the saving to the country is in excess of $4,000.00 per man excluded for either tuberculosis or established non-tuberculous pumonary infection and alternatively that is the cost to the country for each case of

either condition which is not recognized and excluded during the preliminary examination. This is the responsibility which must be assumed by those who decide upon the method to be used and equally upon those who interpret the films. And because of this fact, coupled with the accepted fact that the roentgen examination is the most accurate means we have for the purpose, it should be obvious beyond any question that *the cheapest method is the one which is the most accurate* and that any method which introduces the possibility of an error of any magnitude is "penny wise and pound foolish," apart altogether from its effect upon human health and well-being. In one unit of 800 men of which I have knowledge there were discovered 20 cases of open tuberculosis. The examination of these 800 men cost the country $1,600 and might be said to have saved $4,000 to $5,000 for each of the 20 cases, or a total of $80,000 to $100,000. But the potential saving is far greater than this when the possibilities of infection of others is considered and the point is too obvious to require elaboration.

3. Accuracy. The statement that the roentgen examination is the most accurate method available is true only if the films are technically of really excellent quality. And it must be admitted that the chief criticism which may be brought against the plan of having this work done in any center where roentgen facilities exist is that the general average of the quality of films produced is below standard. This has been our experience in Canada and I am sure the same would be true in any other country. The error resulting can be overcome only by bringing about a degree of improvement in chest roentgenography which is difficult and would take considerable time, or by having centralized or specialized centers. To a large extent the latter plan has now been adopted in Canada but the method still in use is the single 14×17 in. film.

The Stereoscopic Method. I have always been an ardent exponent of the stereoscopic method and am still convinced that this procedure properly used and with films of proper roentgenographic quality is *the* most accurate of all the methods available. If Nature had not intended us to see stereoscopically she would not have given us two eyes but since she has gone to that trouble and since all our visual impressions of the world around us are stereoscopic, I find it difficult to follow the reasoning of those who say they do not find it necessary or helpful in studying roentgenograms, especially those of the chest. Occasionally it is recommended that instead of single 14×17 in. films, two films be made with a tube shift in order to visualize lesions lying behind the ribs, etc. Stereoscopic films have this advantage even if they are not studied stereoscopically as they should be.

Some years ago I made a study intended to establish the relative accuracy of the stereoscopic method as compared to the single film and reached the conclusion that the stereoscopic was more accurate in the recognition of early or minimal lesions by at least 5 per cent in addition to providing fuller and more accurate information about all types of lesions. This percentage may be considered too small to justify the added cost and trouble. Yet the record of the last war shows that "those enlisting at the minimum age (18–20) suffered a high death rate from disease, chiefly tuberculosis," and that among pensioners "23% of the deaths were caused by tuberculosis and the men averaged two years in the hospital."[1] Up to the present pulmonary diseases have been three to four times as common as the next lowest form of illness or disability in the Canadian Army.[2]

Routine roentgen examinations of even a moderate standard of accuracy will undoubtedly prevent a repetition on so large a scale but only the best type of examination will find and exclude many of these minimal lesions in young recruits. If the choice is between no roentgen examination at all or single films, as is frequently the case in civilian work, undoubtedly the proper decision is in favor of single films, even if the quality may not be all that is desired.

I have had no opportunity to reach a personal opinion regarding the accuracy of the

fluorographic method, but believe that the 4×5 in. film is correctly rated as second in point of accuracy to the single 14×17 in. film. I would not hesitate to offer the opinion that if it can be operated stereoscopically in a practical way it would probably constitute the ideal solution of the problem of mass chest surveys. Certainly it should be possible by restricting its use to specialized centers to maintain a higher and more uniform technical standard than can be hoped for from single films from a great multitude of centers ranging from good to bad. There should, however, be no illusion as to the fact that when *all* the items of expense are included in connection with this procedure it is not cheaper and may even be more costly than that in everyday use. To point out that the film used represents a reduction of 50¢ per examination is merely financial juggling and means nothing unless all the other costs are included.

When this paper was first suggested to me, it was hoped we might be able to secure some figures based on the experience of Canada during the present war which might enable us to estimate the degree of accuracy of the 14×17 in. single film and to discover the more important sources of error. It has not been possible to obtain sufficient information to be conclusive and probably will not be for several years, but certain facts are available which are of interest and perhaps of some significance.

Up to the end of May, 1941, there have been 895 men discharged from the Canadian Army because of pulmonary tuberculosis. Of these the majority had been taken into the army in the first days of mobilization before chest survey roentgenograms were routine or who for some other reason did not have chest films on enlistment. This observation is of general interest as an indication of the great value of the roentgen-ray method since all these men had been passed as fit for service by Medical Boards. For further study the records of these cases have been subdivided as follows:[3]

Group 1. Those cases showing an active tuberculous infection *at the first roentgen examination* (i.e. as noted above, this had been omitted for one reason or another until after they had been attested and taken into the army).

Of these 252 cases have been found. Further study of these cases shows the gradual improvement brought about by the general adoption of routine chest roentgenograms:

Found in the last 6 months of 1939—141 cases
Found in the first 6 months of 1940— 50 cases
Found in the last 6 months of 1940— 27 cases
Found in the first 6 months of 1941— 0 cases

Group 2. Cases showing quiescent tuberculosis at the first examination (i.e. clinical) but when reviewed by roentgenograms considered too great to permit remaining in army. (Reason for these men being in the army same as for Group 1.)

In this group there were 425 cases as follows:

Found in the last 6 months of 1939—228 cases
Found in the first 6 months of 1940—116 cases
Found in the last 6 months of 1940— 79 cases
Found in the first 6 months of 1941— 2 cases

Group 3. Cases where the original film *showed evidence of tuberculosis* but which were reported "negative" by the roentgenologist, but who later had active tuberculosis.

This group is perhaps of the greatest interest as indicating the degree of personal error. For this purpose the enlistment films were obtained and a comparison made with those taken subsequently or the film taken upon discharge as the case might be.

In this section there have been discovered up to the present 11 cases out of a total of 328,325 examinations, or a percentage error of 0.003 per cent. It is highly probable that this type of error, insignificant though it is, is almost always due to fatigue since in all of the above 11 cases there was no disagreement as to the presence of the disease when the original films were reviewed. It had simply been overlooked by competent men in the press of work.

Group 4. In this section were placed those cases in which the original film was reported "negative" and on review is still considered "negative" but in which tuberculosis developed after enlistment and has been verified by subsequent roentgenograms.

In this group 16 cases have been found up to the present, i.e. 0.004 per cent. This may be said to represent an inaccuracy inherent in the method since all observers have agreed that the original films do not show a tuberculous lesion. How much would we not give for stereoscopic studies in these cases! Still it would be hard to justify stereoscopic roentgenograms of all the others in order to find these 16 even if it were successful in doing so, which we have no means of finding out.

Group 5. Those cases which were reported as "doubtful" on the initial roentgen examination but considered "fit for service" on clinical grounds but who later broke down under service.

In this group there have been discovered 9 cases to date. This figure is so small as to be insignificant except perhaps as an added reason for the exercise of the greatest caution in admitting to the active service forces any type of tuberculous cases no matter how small the "doubt" may be.

The greatest source of error has been and is likely to continue to be found in the *failure to recognize early evidences of non-tuberculous* infections. This involves both the type of film available for study and the experience of the roentgenologist in interpretation. Andrus has done excellent work on this subject which deserves close study by every roentgenologist. His conclusions have been reached from the study of single 14×17 in. films using stereoscopic examinations for the detailed study of special cases. Peirce has made an important contribution along the same line by a simplification of bronchography which now becomes a procedure every roentgenologist can carry out almost routinely in suspected cases.

Whether this work can be as well done by means of fluorographic methods remains to be seen but unless it can the value of smaller films would be greatly reduced. When these films were first introduced it was emphasized that in order to secure satisfactory films high capacity apparatus was required using exposures of not more than 1/10 second. Now it is suggested that in order to permit this type of apparatus being used in mobile trucks the exposures are to be prolonged to $\frac{1}{4}$ to $\frac{1}{2}$ a second, using smaller and cheaper generating equipment. Surely this step would take us back fifteen years and nullify much of the effort which has been devoted during that time to improving chest roentgenography. If, on the other hand, it can be shown that the method is equally accurate or even nearly as accurate, it should be a welcome addition since it would make possible a great extension of the roentgen examination in mass surveys of the chest and open up fields which otherwise might never have the advantage of this procedure because of the expense involved.

SUMMARY

1. The results of the use of single 14×17 inch chest films in 328,325 recruits for the Canadian Army are given, 3,076 having been rejected for tuberculous and 1,088 for non-tuberculous pulmonary infections.

2. There are twenty-seven known errors in this number of examinations which is comparatively insignificant. Of these, eleven were "personal" errors due to errors in interpretation and therefore presumably avoidable while sixteen were considered inherent in the method and unavoidable. Even if others are discovered later, as will probably happen, the use of single 14×17 inch films has proved to be highly accurate as a means of discovery of tuberculosis carriers and amply justified on economic grounds.*

My thanks are tendered to Brigadier R. M. Gorssline, Director General of Medical Services, Canadian Army, for information supplied and permission to make use of it.

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* For discussion see page 79.

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TECHNICAL FACTORS UNDERLYING MINIATURE ROENTGENOGRAPHY OF THE CHEST*

By HOLLIS E. POTTER, M.D.
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THE sharp interest recently developed in fluorography is simply the further expression of a persistent demand on the part of tuberculosis workers for an adaptation of the roentgen method more economical and less cumbersome than the conventional system. Gradually year by year the roentgen method has rightfully earned its place as the one most important step in determining the presence, extent and pathologic character of pulmonary tuberculosis. Whenever a fluoroscopic or fluorographic short-cut is contemplated it is only right that the conservative internist and the conservative roentgenologist reserve judgment until proofs of diagnostic accuracy are available. It is my impression that miniature fluorography at its best now offers a definite short-cut in technique and unit cost without an appreciable sacrifice in diagnostic accuracy.

The idea of photographing the fluorescent screen is nearly as old as Roentgen's original discovery. Many of us here and abroad have tried it out from time to time. We concluded from our failures that some factor in the assembly must be too slow. We now know that each and every factor in our assembly was much too slow to obtain proper chest roentgenograms in one-tenth of a second. In this paper I shall give a brief explanation of the developments in recent years which now furnish the underlying basis for successful and practical speed fluorography.

In my opinion, the ideal miniature chest film while much smaller than a direct roentgenogram should still be large enough to serve exactly in its stead. Technically it should be equal in diagnostic quality to a film of the same size reduced from a direct chest film. Also to serve its purpose it should be simple to read, to file and to review at any future date. We may say that this ideal has now been approximated but not absolutely reached, for reasons to be explained.

The problems in technical development have largely consisted of a search for speed and yet more speed. Proceeding systematically we should first record that speed in generators and tubes we already had in large degree before the advent of really rapid fluorescent screens. The practical perfection of the rotating anode tube has further guaranteed an efficient maximum source of roentgen rays for this purpose and much of the best work has been done with this tube.

In 1933 there first appeared the fluoroscopic screens upon which miniature work now depends. Both here and abroad zinc-cadmium sulphide screens were furnished. They give a yellowish-green fluorescence and have been most commonly used in making the 35 mm. miniatures since stock movie film sensitive to green is easily obtainable. Patterson coats and markets this screen as "Type B." He has since furnished a zinc sulphide screen which fluoresces blue-violet which he calls the "Photo-Roentgen" screen. He describes this screen as being made from salts of zinc sulphide, activated somehow with silver and damped for lag with some nickel salt, all furnished him by Dr. Leonard Levy and Mr. Donald West of London. In the making of fluorescent screens, as in making films, the exact composition of the salts, their method of preparation, and the process of coating are facts best known to the individual manufacturers who seldom burden us with too much definitive data.

Prior to 1933 you will remember the old platinocyanide screen of Edison, 1896; the calcium tungstate screen perfected by Geh-

* Read at the Forty-second Annual Meeting, American Roentgen Ray Society, Cincinnati, Ohio, Sept. 23–26, 1941.

ler about 1910 and further improved here by Edwards and then Patterson between 1912 and 1918; the zinc silicate or astral screen of Germany; the English calcium sulphide screen and the cadmium tungstate screen perfected by Patterson in 1914. All of these older screens, while serving well for fluoroscopy or intensification, had brilliancy and actinic character far below the present day fluorographic screens. Exact ratios are difficult to express because of the difference in color characters.

With all their speed the present fluorographic screens are not entirely perfect. In order to obtain the maximum speed relatively large crystals of the sensitive salt must be used. Unfortunately it is a fact that the larger the crystals, the greater the tendency to dull the acute sharpness of the fine hair line details of lung structure. It is truly fortunate, on the other hand, that the early recognition of minimal tuberculosis does not depend on minor differences in hair line detail sharpness since the lesions are not linear but nodular or irregular mass forms.

If at any time a greater lens or film speed should be developed then smaller crystals could be used in the fluorographic screens and a little further detail in hair line structures would result. Under present conditions the London contributors of fluorescent salts can promise no significant improvement in their product.

Another very important factor in fluorography is that of the recording film used. We have said that the film selected must be color sensitive to the greenish zinc cadmium sulphide or the bluish zinc sulphide fluorescent screens. In the beginning it was thought possible that somewhere in the world special speed films had been produced which might happen to be more adaptable to this use than any with which we were familiar. A laboratory assay of all available film soon showed that for the zinc sulphide screen blues there was none better than the familiar roentgen-ray emulsion and for the yellowish greens of the zinc cadmium screen none could be found that excelled the common movie film.

Film manufacturers have been urged to figure out a still faster emulsion yet having the same good working qualities, and some favorable results have been obtained. Since 1937 the Eastman Company has brought to us the Blue Brand duplitized film which was a definite contribution to work with the 4×5 in. roentgenograms. They have recently produced another film with a complex single emulsion which tests out even better in certain respects. I am told that even much higher speed in film emulsions is possible for this purpose provided the film is used without appreciable delay since the emulsion would have to be somewhat unstable. Some of our manufacturers have clung to the shortsighted policy of opposing fluorography for fear it would lower the requirements for conventional sized films. This fact has probably slowed down research in one of the most vital and promising divisions of fluorographic progress.

An important aspect of miniatures is that of film grain—the faster the emulsion the larger the little silver granules which are not ordinarily detectable in our films until they are enlarged. While care in development with fine grain developing solutions considerably prevent grain prominence, it is a fact that 35 mm. speed film treated in an ordinary tank of hydrometol developer gives a grain prominence which is not only objectionable when re-enlarged for viewing but actually detracts from its diagnostic merit.

In thinking of film size in connection with grain, we should think not in terms of diameters but of areas, for it is quite obvious that in multiplying the diameter of the image four times there is available sixteen times the number of little grains for recording the image. The rest of the story is that when the 1 square inch is multiplied to 16 square inches the grain effect is not only fractionated by that amount but there is obtained a 4×4 in. film which no longer needs enlargement but can be read first

hand. It is a matter of common observation that in 4×5 in. miniatures there is no grain problem.

Now it is true that between the 1 inch square and the 4 inch square miniatures there are many intermediate sizes which have been given consideration in other countries. For instance Zakovsky working in Holzknecht's laboratory in Vienna reported in 1940 that after much experimentation he had adopted single 6 cm. (2.3 in.) films with a stock German lens. At a June, 1939, meeting of the roentgen-ray industry in Berlin it was resolved to utilize for the time being the standard aeroplane lens and film covering a square 6.8 cm. (2.7 in.) in diameter. Janker in Bonn has recommended a single film technique using films 7 cm. ($2\frac{3}{4}$ in.) or even 9 cm. (3.5 in.) in diameter. From this it can be seen that these workers have made every effort to utilize available lens and film combinations, all far above the original 35 mm. size and still usually needing slight re-enlargement for reading. It has been brought out that detail loss from light dispersion occurs when re-enlargement of more than two and one-half diameters is used.

I will admit some personal controversy with Dr. Rex B. Wilsey of the Eastman Company on the topic of grain in duplitized film as compared with single emulsions. I have previously expressed the idea that in the double coating the grain effect of one emulsion tended to fractionate the effect of grain in the other emulsion. He argued that in direct viewing of a 4×5 in. film there was no grain problem and better detail could be obtained when a single coating is used. After looking at the latest single coated product from Eastman Company I admit he may be right. It does show better detail. The whole subject of grain size and shape is now being studied by the electron microscope with definite promise of better understanding of grain form but with no advance promise of its elimination.

The other primary and important factor in speed fluorography is the lens. Since the advent of the modern rapid screen the research on miniatures seems to have hinged on the subject of available lenses and the films commonly used with them. We are all familiar with the excellent candid camera lenses which range in size from 35 mm. to $2\frac{1}{4}$ in. We are not nearly so familiar with the research and development which has produced the larger lenses of equal or superior quality for use in aeroplane photography. For this purpose, the world's most skillful lens makers have produced lenses having sizes and characteristics never before attempted.*

In the beginning full appreciation was acknowledged for the pioneer work with 35 mm. film being done by de Abreu and others but after some experimentation this was set aside as inadequate. Then followed work with larger lenses until the 4×5 in. size was reached. Lenses of this size more rapid than f:3.5 were not to be found commercially. However, it was found that Bausch and Lomb had previously made an f:1.5 lens from imported glass which would cover nearly $3\frac{1}{2}$ inches properly. The lens was intended to take night photographs from a rapidly moving aeroplane and was successfully borrowed for a short period. Fluorographic results were obtained which proved to our entire satisfaction that the ideal chest miniature could be obtained by concentrating on this size, this speed and the best film obtainable. The area of the 4×5 in. film is about fifteen times the area of the 35 mm. film and one-twelfth the area of the 14×17 in. film. There was no apparent reason why it should be any larger. There were many reasons why it should be no smaller. Work was immediately begun in earnest. Glass blocks for a limited number of lenses were obtained from countries now at war. At that time the glass required for one or two of the six elements in the lens

* I may explain at this time that I was invited at an early stage to cooperate with the General Electric Company in a thorough-going and expensive inquiry into this subject and that while I merely acted as an adviser, I have had the privilege of approving all of the underlying technical details used in their present apparatus. I naturally think it most nearly the ideal instrument obtainable today.

could not be made in this country without flaws or discoloration. With the first complete unit we first made sixty-five comparisons between various stages of tuberculosis as shown in the regular way and on miniatures, sometimes taking a dozen miniatures on each case to study variations in technique. This apparatus was then loaned to Drs. Douglas and Birkelo at the Herman Kiefer Hospital in Detroit who started its use by doing about 1,600 comparisons as an unprejudiced field test. Thanks for their interest as well as that of the Health Commissioner, Dr. Henry Vaughan, is hereby acknowledged. Trips to Detroit convinced a number of tuberculosis workers that the evaluation of results was being conducted in a most unbiased and scientific manner.

The war came and proper foreign glass was no longer available. The story of how the Bausch and Lomb Company improved the formula, succeeded in making all the glass elements and finally produced this large lens specifically adapted to fluorographic work is one of a victory of no mean proportions. Here are a few of its specifications and attributes in brief. It has a 6 in. focal length and 3 in. aperture. It belongs to the anastigmat series and is corrected for all objectionable aberrations. It gives good definition over a wide field of coverage and is unusually large for its speed. Compared with the original lens, greater detail and more even illumination over a greater area is obtained and the lens is less critical to focus. Its resolving power is expressed as 57 lines per millimeter at center and 50 lines per millimeter at top and bottom of the 4×5 in. film.

Rated optically at f:2.0 it has been speeded up by the application of the very new coating of monomolecular films on the eight air-to-glass surfaces, the outer surfaces being coated by means of an acid process which allows handling and cleaning as with an ordinary lens. The inner elements are coated with a metallic fluoride by a vacuum evaporation process. These coatings serve to reduce light reflections and increase light transmission so that as used in fluorography the lens is increased in speed to approximately the equivalent of an ordinary uncoated f:1.5 lens. Above and below the field of absolute flatness of definition the fluorescent screen is mounted with a slight curvature to match the curvature of field so that areas above the pulmonary image which is used for identification markings are brought into sharp focus.

It would not appear probable that any further improvements in lenses would be made known until the foreign conflict is settled. At that time access may be had to some valuable improvements in aeroplane lenses, particularly from England and Germany. A prediction can now be made that those still forced to the micro films of the candid camera lenses and who do not accept the 4×5 in. size as ideal will hasten to acquire the splendid lenses produced for aeroplane cameras.

The grid diaphragm is an instrument of no small value in fluorography particularly when a focused parallel non-moving grid is used in connection with certain types of film emulsions which seem to need the diaphragm to prevent fog. As new and faster emulsions appear it is probable that such grids will be used in routine. On miniatures even as large as 4×5 in., the fine grid lines of the stationary grid made with fifty grid members to the inch is not visible to the naked eye although strongly visible under the microscope. The most recent experimental emulsions by the Eastman Kodak Company benefit greatly by the use of such grids.

The stereoscopic principle is now being used to considerable advantage in fluorography as in regular size films. The stereoscopic shift occasionally prevents small flecks of tuberculous areas from being overshadowed and obscured by an overlying rib. A 4×10 in. film holder and a small stereoscope are available.

The use of films in rolls seems rather advisable for the very small miniatures but for the larger sizes the single exposure film holder is preferred because so frequently

patients appear in groups numbering over or under the number of films in each roll.

Since fluorography is intended to be used by those who require large numbers of chest films each day the original expense of the apparatus is soon absorbed by the saving in films and chemicals. Thereafter the apparatus works on and on toward the objective of finding and caring for the innocent victim of tuberculosis so that ultimately it may be wiped out or reduced to a minimum far below present day figures.

Because of the proved diagnostic superiority of the 4×5 in. film, tuberculosis survey men, working on even a limited budget, may not have to differentiate between one cent for a 35 mm. film and five cents for a 4×5 in. film.

The same men by their economy in case finding will be able to use regular size films for more detailed study of the positive cases, to periodically check their progress and to help determine the special treatment required for each. The reduced cost in case finding has already relieved certain budgets so that conventional size films could be lavishly used in collateral research. The reason for thus emphasizing the matter of cost is based upon the proof of wholesale wastage in case finding programs by other roentgenologic methods. One need only mention that in the age group below fifteen years the cost before fluorography was over four thousand dollars to find a single case. Reports on economies in the survey of hundreds of thousands of individuals are now coming through rapidly.*

* For discussion see page 79.

EVALUATION OF METHODS FOR MASS SURVEY OF THE CHEST*

By ARTHUR C. CHRISTIE, M.D.
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INTEREST in roentgen-ray survey methods of the chest has greatly increased in the past two years due to their use in examination of recruits for the Canadian Army and their adoption in the United States Army and Navy.

The reasons which impelled the Medical Departments of the United States Army and Navy to adopt methods of roentgen-ray examination of all recruits are briefly stated in the following recommendations of the Sub-Committee on Tuberculosis of the Committee on Medicine of the National Research Council:

(1) At least 75 per cent of early active tuberculosis can be discovered only by x-ray examination.

(2) About one per cent of the male population of military age have active tuberculosis, most of which can be detected only by x-ray examination.

(3) A high proportion of cases of early tuberculosis, detectable only by x-ray examination, are likely to break down under such strain as that entailed by military duty, incapacitating them for further service and making them a menace through contagion to their comrades.

(4) X-ray examination is much more expeditious than physical examination, thereby saving considerable time in the general examination.

(5) X-ray film examination furnishes a permanent and authoritative record which may be useful in subsequent medico-legal adjustment.

(6) Other conditions than tuberculosis which would make the registrant unfit for military duty may be discovered by x-ray examination.

(7) The procedure will amply repay the cost by the saving of effective military man-power and reducing the ultimate cost to the Federal Government in pensions.

During the World War of 1914–1918 many recommendations were made, especially by Drs. Lewis Gregory Cole, Leon T. LeWald and other radiologists, for the roentgen examination of the enlisted personnel of the Army and Navy. The reasons for non-adoption of the method during that war are brought out in a valuable article recently published by Spillman.† It is sufficient to say here that radiology did not then have the standing in the medical world to enable it to establish its case. One of its greatest handicaps was the small number of radiologists and medical men trained in interpretation of chest roentgenograms. These defects have been overcome in the intervening years. The roentgen-ray is now recognized, not only as valuable, but for the early diagnosis of pulmonary tuberculosis, more valuable than all other methods combined. There are now available large numbers of radiologists and specialists in tuberculous disease capable of expert interpretation of chest roentgenograms. Great strides have also been made in the technical fields.

There is now general agreement that everyone entering the military service should have a roentgen examination of the chest and that the examination should be such that the resulting picture may be permanently filed with the man's record. It would seem to be a necessary part of the procedure in order to complete the soldier's record that he have another examination upon his separation from the service. It has also been suggested that roentgen examination of the chest is desirable at least once during a three-year period of service. This latter suggestion may not be of great practical importance. There is, as yet, no very strong evidence that adult exogenous infection is a frequent cause of pulmonary tu-

† Spillman, R. Value of radiography in detecting tuberculosis in recruits. *J. Am. M. Ass.*, 1940, *115*, 1371–1378.

* From the Radiological Clinic of Drs. Groover, Christie and Merritt. Read at the Forty-second Annual Meeting, American Roentgen Ray Society, Cincinnati, Ohio, Sept. 23–26, 1941.

berculosis, and even if it were, the original examination can be expected to eliminate most of the sources of infection.

As stated above, it is now generally agreed that everyone entering the military service should have a roentgen examination of the chest. There is, however, no general agreement as to the type of examination which should be adopted. It is not likely that anyone would now advocate fluoroscopic examination except as a makeshift in localities where roentgenographic examination is impossible. The objections to it are the danger to the operator, the relatively low percentage of accuracy in diagnosis, and the absence of a permanent film record. The failure of agreement upon the particular roentgenographic method to be adopted is shown by the fact that the Canadian Army has used the 14×17 in. film and that the United States Army has adopted the fluorographic method with 4×5 in. film and the United States Navy the fluorographic method with 35 mm. film, and that the paper film has been used in examination of a large number of selectees and has strong advocates. Each method has certain advantages and each of them, including the 14×17 in. film, its disadvantages. These advantages and disadvantages have been variously stated by different committees, commissions and individual investigators. It is acknowledged by everyone that the 14×17 in. film method is the best. It is most accurate in diagnostic detail and for this reason it is the *only* method which should be employed for accurate diagnosis of type and extent of disease and for careful comparative study of the progress of disease. This point should be emphasized here and should be constantly recognized by all who advocate methods of roentgen survey for the segregation of cases of pulmonary tuberculosis. Its full acceptance, however, is not an argument against the use of other methods which are practical for purposes of survey even though they may not be acceptable for complete diagnostic study of individuals with tuberculosis.

The chief disadvantage of the 14×17 in. film method is its cost. It is true that Spillman and others have shown that even the high cost of chest examinations of 14×17 in. films is much more than offset by the losses entailed by acceptance into the military service of a considerable number of cases of active tuberculosis. Its use is therefore fully justified until less expensive methods are demonstrated to be effective and practical. A second objection is its relative slowness in operation. With one installation about 200 examinations a day is the maximum. A third objection which is of real importance is the difficulty of filing and preserving films of such large size.

The three methods which may properly be called "survey methods" are the roentgenographic paper method of the Powers Company, and the two fluorographic methods, one with 4×5 in. film and the other with 35 mm. film.

The paper method has been in use for several years and has been employed especially in surveys of large numbers of school children. My own experience with this method has been in examination of several thousand high school students in the District of Columbia under the direction of the District of Columbia Tuberculosis Association. The results of these surveys are indicated in a general way by that made in the fall and winter of 1940 when 4,115 students were examined. Seven were reported with definite tuberculous lesions thought to be active. Twenty-five had suspicious apical or hilar changes for which further study was recommended. Abnormalities of the heart shadow were found in eighteen. Hodgkin's disease or lymphosarcoma was found in two. Smooth tumors thought to be dermoid cysts, two. Various degrees of calcification were reported in thirty-three.

The value of this method for survey of groups of people has been thoroughly demonstrated. It serves to find and segregate a considerable number of persons with active tuberculous lesions and a further number of inactive cases who may need treatment themselves or who will guide the Health

Department to the active cases which were the source of their infection. A number of other conditions including spinal abnormalities some of which will require treatment or advice will be discovered in every survey. To argue that a few more cases of tuberculosis would have been discovered had the students been examined by means of a 14×17 in. standard film is beside the point since such examination was considered impractical and would not have been carried out.

The roentgenographic paper method has not been considered practical for use in the military service. In civilian surveys the method has made use of the paper in rolls which is very convenient for making the exposures, processing and interpreting. For the military it is necessary to have the films separate for each individual. This slows the process somewhat but it is still practical. The objection to the size, 14×17 in., for final filing with the soldier's record can be overcome by making small reductions. This can be done without materially lessening the quality of the roentgenogram but of course increases the time for processing and the total cost.

The advantages and disadvantages of the two fluorographic methods may be stated as follows:

(1) *4×5 inch film*

Advantages: Relatively low cost (approximately one-tenth that of 14×17 in. film). Speed of operation about 60 per hour. Readable without enlargement. Low storage requirement. May be filed without change with the patient's record.

Disadvantages: Cost of original equipment for photography is high and is in addition to the roentgen-ray equipment which must be capable of at least 200 ma. output.

(2) *35 mm. film*

Advantages: Minimal expense (one-fiftieth that of 14×17 in. film). High speed of operation, about 150 per hour. Ease and convenience of storage. Photographic unit available in large number and not expensive.

Disadvantages: Projection or magnification is required for reading the film. Less convenient than the 4×5 in. film for filing with patient's record.

Obviously diagnostic accuracy is a most important element in judging the relative value of any method of roentgen examination. I have not included it in the above discussion because it is not so objectively arrived at as the other advantages or disadvantages. With regard to relative diagnostic accuracy of the three survey methods here being considered, I am stating below my own personal opinions knowing that others hold opinions which differ from mine. My opinions are based upon examination of many thousands of cases examined by the roentgenographic paper method, and about eight hundred by the 4×5 in. method. In all of the latter a 14×17 in. film was made as a check. I have had no personal experience in making examinations by the 35 mm. film method but have had the opportunity to examine many of the films and to compare them in numerous individual cases with the corresponding 14×17 in. film and in many cases with the 4×5 in. film.

I have arrived at the opinion that all three methods are acceptable as survey methods, but I prefer the 4×5 in. film method to the other two for the following reasons:

1. In diagnostic accuracy I find that the 4×5 in. film the most reliable, the roentgenographic paper next and the 35 mm. film the least reliable.

2. For permanent record the 4×5 in. film is readily and permanently filed with the person's record without reduction as is necessary with the roentgenographic paper or 14×17 in. film and without special mounting which is necessary with the 35 mm. film.

3. The 4×5 in. film is readily examined at any time without special illumination, magnification or projection.

4. I find the study of the 35 mm. film productive of eyestrain and exceedingly tiring which is not true of the 4×5 in. film.

The most determining factor in my preference for the 4×5 in. film method is my conviction that the quality of the film is much superior to that of the other two methods. I rate it in diagnostic accuracy very close to the 14×17 in. film. In fact, for minimal lesions I would feel more certain of their detection by means of two 4×5 in. films made with a tube shift than I would with a single 14×17 in. film of the best quality. I have been greatly impressed by the importance of taking two films of every chest in a survey. Shifting the tube serves to uncover portions of the lungs which may have been obscured by bones or other structures in the first roentgenogram. This also enables one to have the additional advantage of stereoscopy if he desires it. The U. S. Army Medical Department now has its films made in the 4×10 in. instead of 4×5 in. sizes, so that two fluororoentgenograms are made in each case and they are readily examined stereoscopically.

Recently Major de Lorimier at the Army Medical School has been working on what gives promise of being a real advance in this method, namely, the use of a single-coated instead of a duplitized film, a fine grid being used to compensate for a higher voltage which is necessary. There is good promise that the detail in the single-coated film will be better than that in the duplitized film. Screens of finer grain will of course improve the quality of both the 4×5 in. and the 35 mm. films.

Whatever method is finally adopted there is no doubt that everyone entering the military or naval service of the United States in the future will have a roentgen examination of the chest. The advantages of such a course are now beyond argument.

The use of mass surveys for the civilian population is more difficult to put into practice but the method has been gaining ground for several years and is now being used quite extensively for examination of high school students and to a lesser extent of industrial and college groups.

A hundred years ago the mortality from tuberculosis in the United States was about 400 for every 100,000 in the population. Today it has been reduced to about 50 to 60 per 100,000 of population. It varies greatly in different localities and in different groups and races but an average death rate of 50 per 100,000 is believed to be in sight. This means that we still face the problem of the deaths of 65,000 persons per year in the United States from tuberculosis unless we can devise more efficient means for prevention of the disease. The effective means for prevention is discovery of every case of pulmonary tuberculosis at an early stage. There seems little doubt that this can be accomplished by mass roentgen surveys of the adolescent and young adult population. It is not too much to say that a method which will reveal about 100 persons in every 10,000 examined with active pulmonary tuberculosis which was not until then suspected would constitute an epoch-making advance in public health.

I will not here discuss the practical aspects of putting such a program into effect. It is a public health program of great importance which I believe radiologists should support and encourage. It is my conviction that it could be made very practical in every urban center and even in thickly settled rural counties in a relatively short period through cooperation of the local health departments, tuberculosis associations and the medical profession.

DISCUSSION ON PAPERS BY RICHARDS, POTTER AND CHRISTIE

Dr. Carleton B. Peirce, Montreal, Canada. I consider it a great honor to open this discussion, but I shall not attempt to consider all the details which have been presented by the essayists. I shall leave to Dr. Dunham detailed comment on the relative efficiency, accuracy, and dependability of the several types of chest examinations. He has taught us more about the roentgenology of tuberculosis than anyone else.

Dr. Potter has made an exhaustive study of the technical features of miniature chest roent-

genography, and I would not presume to discuss those details.

However, it is my personal opinion so far, that I would not trust my own opinion on the presence or absence of either minimal tuberculosis or disabling non-tuberculous disease, disease of relatively low visibility (as bronchiectasis sicca) as portrayed on the miniature film, any more than I would on a straight fluoroscopic study.

I have had occasion to check myself in a comparison of the fluoroscopic study with the full-size film, both single and stereoscopic. I know very definitely that fluoroscopic evidence is not sufficient for diagnosis of minimal tuberculosis or minor manifestations of disabling non-tuberculous disease, which we know very definitely must be considered in any military force.

I should like to call attention to the following points:

First: Upon the declaration of war the radiologists throughout Canada were of the opinion individually and collectively that it was their duty as members of the Commonwealth to devote their full energies to assist the military authorities in a chest survey of all military personnel. The Government offered a flat rate per soldier, which was adequate to cover the outlay for the cost of materials and at least a portion of the non-professional labor. We had only the period from early October until the middle of November before the first troops, in any quantity, were to sail; therefore, it was necessary that this be done quickly, efficiently and accurately. As a result, the radiologists throughout the country voluntarily laid aside any consideration of fees for their own labor, took on the job, and got it done.

The individual films were first sifted by the radiologist in whose office or hospital the film examination was accomplished. The roentgenograms of all that were accepted or approved by him were then submitted to a board of review sitting in Ottawa. That board consisted of from three to twelve senior radiologists sitting periodically, sometimes almost continuously throughout whole weeks, and definitely over each week-end. There, in conference between the individual members within the group, final approval or disapproval on uniform standards was accomplished.

Second: As criteria for approval of military personnel, at the outset of the war, with the advice of this group of roentgenologists, the Consulting Radiologist in the office of the Director General of Medical Services established certain criteria upon which men were to be classified. It was decided that as to tuberculosis, we would consider three classifications:

1. Residual evidence of previous tuberculosis; calcareous nodules or fibrotic scars in the parenchyma or in the hilum considered as manifestations of old tuberculosis, but in which the lesion presumably would not break down in the military service.

2. Latent tuberculosis with evidence of a focus still soft, or not sufficiently hard to warrant an opinion by the roentgenologist that this was a relatively insignificant lesion for the immediate future, particularly under the stress and strain of military life.

3. The minimal lesion with little or no clinical manifestation of tuberculosis; cases of gross adenopathy with or without appreciable calcification zones; and the frankly adult type of reinfection with or without tubercle bacilli in the sputum.

Group 1 was considered safe for approval. Groups 2 and 3 would not be approved.

Dr. Richards has called our attention to the effectiveness of the Canadian sorting. Permit me to emphasize the matter of fatigue on the part of the roentgenologist reading a large group of films. All experienced roentgenologists are aware of this problem. I am proud of the Canadian record of only 11 missed out of the first 328,325. This is an inherent potential error of any mass survey. But I am inclined to believe from some personal experience and familiarity with chest roentgenograms that the miniature film will not afford any relief of this fatigue error of 0.004 per cent, and has considerable potentiality for increasing it.

Further, attention should be called to the group showing scars (but considered safe for military service) which in the Canadian experience so far has shown nine breakdowns to clinical tuberculosis under service conditions. I would emphasize Dr. Richard's warning that men in this category should be approved for active military service only with extreme caution.

The number of men developing tuberculosis after an apparently clear chest film is remarkably low and offers considerable compliment to the careful sorting, as well as emphasis on the wisdom of the general policy. I do not agree with Dr. Richards that this can be an inherent

accuracy in the method of examination. Stereoscopic films probably would not have reduced this percentage of 0.004 materially. Some of these men may have contracted their tuberculosis from contacts with the civil population.

Third: As to economy, certain advantages have been described relative to the usability of these "miniature" films later on, as in the dossier or service record of the individual soldier. A large percentage of persons do not know how to handle films, particularly small films. I would wager that by the time a man's service record gets through one regimental headquarters, these films will be so pockmarked with fingerprints that they will not be very usable. Although there are difficulties in the storage of large-sized films, they are less likely to be damaged in handling.

Another point made by Dr. Richards should be seriously considered, namely, the matter of the interpretation and availability of service. The expense of transportation of men as well as the purchase of special equipment for miniatures will not be offset by the relative saving in mere cost of sheet film. And as to interpretation, I should like to quote a statement made by Dr. Bruce Douglas, one of the workers in tuberculosis with whom many of you are familiar:

"There is an impression abroad that the roentgenogram will reveal very definitely whether tuberculosis is present or not, and that when it is present it is so simple that 'he who runs may read.' Such is not the case. Experience in interpretation is most important, and the interpreter, having found evidence of a lesion, will wish to support his opinion with other pertinent data."

Finally, I would call to your attention to the fact that although the Dominion of Canada has been interested in carrying on its job in this war with the minimum of expense so as to put less of a burden on the future tax payers, that Government enlisted and enjoyed the full support of all its experienced roentgenologists in the interpretation of the films. As an American citizen, although resident in Canada, I regret that the United States Government is not making as full use of the talents of its own roentgenologists in this important problem.

Dr. H. Kennon Dunham, Cincinnati, Ohio. I have never been complimented so much in my life as I have been today—these three magnificent papers, timely, valuable, to the point, are to be discussed by me in five minutes. The other compliment I get is that here we have three magnificent papers all coming in saying you must have a roentgenogram of the chest or you don't know anything about what is inside of it, and I have been trying to say that for nearly forty years.

The other thing I want to say is that I vote for the new 4×10 in. stereoscopic film, which I believe is going to revolutionize mass examinations. I don't think there is anything I have seen in the whole work of roentgenology which appeals to me more than the stereoscopic 4×10 in. film. It is going to be on exhibition, and I think you will all want to look at it. I believe, as Dr. Potter said, it is a little better than the single 14×17 in. I am glad to have heard these papers—they are real and they are important to every one of us.

Major A. A. de Lorimier, Washington, D. C. It is a privilege, I realize, to enter into a discussion on these excellent papers.

The Surgeon-General's statistics relative to hospital admissions because of the diagnosis of tuberculosis would seem to be pertinent to this subject.

(Slide) These plottings indicate rates of admission per thousand, not total numbers in thousands. You will notice there was a definite decreasing trend from approximately 5 per thousand in 1900 to approximately 2 per thousand in 1939.

The abrupt rise during the years of the last great mobilization would appear to be fictitious. There were other mobilizations and periods of concentrations of men during these past forty years, without such a rise.

To students of epidemiology this rise does not appear to be genuine. Some account for it on the basis of health seekers, definite cases of the disease coming in with the hope that their health might be improved or perhaps that they might be cared for by the Government; others claim that this rise can be explained on the basis of rash diagnoses, that is, the using of the term "tuberculosis" when referring cases for hospitalization, and the fact that this diagnosis, or the term "tuberculosis, observation for" remained on the records. Whatever the explanation may be, it is now realized that these diagnoses have led to tremendous expenditures by our Government, expenditures of one sort or another, in all amounting to approximately $1,000,000,000, because of tuberculosis alone.

It is, therefore, obvious that we must consider

this problem of chest examinations in a two-fold manner: (1) with respect to a responsibility for the individual as well as for those about him; and (2) with respect to protection of the U. S. Government.

This second responsibility might be considered as a matter of providing legal evidence. Particularly because of this viewpoint, we have believed it necessary that we accomplish a two-film record and that records be obtained not only before admitting an individual into the service but also that they again be obtained before discharging the individual from the service.

We believe that this two-film record should be *made* stereoscopically, and we favor actually viewing the films stereoscopically.

(Slide) This slide is intended to indicate our analysis of the various methods which might have been adopted.

You might notice that we have considered the possibility of using stereoscopic 14×17 in. films; the possibility of using a single 14×17 in. film; using two paper film exposures; a single paper film exposure; using a stereoscopic 4×5 in. film. (In the beginning we made single-cut 4×5 in. films, and studied them with the conventional Wheatstone type of stereoscope.) We have also considered the use of a single 4×5 in. film, a stereoscopic 35 mm. or a single 35 mm. film and fluoroscopy.

We have evaluated these various methods in terms of: (1) diagnostic trust—and by that we mean the relative trust—with consideration of study of an individual case. (Too often the evaluation of these methods is limited to this one aspect); (2) for our purposes we have had to consider the preserving of the graphic record; (3) we have had to consider the matter of expediting the examination—that amounts to coordinating with other members of the examining team; (4) the availability of supply is no longer a problem, but it was a problem when we first undertook this analysis approximately three years ago; (5) the initial cost of auxiliary equipment, we believe, is of relatively little importance, not because we are inclined to be at all extravagant, but merely because we feel that that expenditures for auxilary equipment are soon cancelled; (6) the matter of unit cost per examination is of some importance. Incidentally, the values that are listed here are based on Government discounts plus the cost of chemicals; (7) this column, which is listed as "Ease of Studying," we believe to be a most important aspect. It has to do with the consideration of studying not one case but hundreds of cases, within a limited period. I believe that Dr. Shanks has expressed this point very adroitly in the following way, quoting him:

"It is a well known fact that viewing a long series of similar films, the vast majority of which are quite normal and without any scientific or other interest, is a very tiring process. The very greatest care must therefore be taken to avoid the wandering attention of fatigue. For instance, armchairs should be comfortable but not too comfortable, and sessions short."

Our view is that we must provide a method which permits ease of study to the extent of providing for continuous accuracy and that method, we believe, is the stereoscopic viewing of these films. We have come to the conclusion that the 4×5 in. stereoscopic method is the best for Army purposes.

At the present time we are considering means of facilitating this work and providing for the maximum uniformity of results. We are trying out the use of higher kilovoltages.

(Slide) We feel that by so doing, we are reducing the load upon the roentgen tube and, moreover, we are providing for reduction of exposure times, thereby obviating some of the maleffects of involuntary motions. You will notice when using higher kilovoltages that the total heat unit load is proportionately reduced. If we do not make use of the waiver grid, we are able now to make exposures in times as short as one-tenth of a second, and when using the waiver grid, our exposure times are one-fifth of a second for most chests.

(Slide) We are also faced with the responsibility of providing for film life. This is a relatively new problem. I believe that most of you study a film with the thought of making an immediate diagnosis, and you may possibly refer to it within a period of a few years and seldom any later. For this work we must anticipate the need for a film life of twenty to thirty years. I believe that within the next few months we will be able to discuss further this phase of the subject, but I am simply showing you the design of a processing unit which is intended to provide for greater film life.

VOL. 47, NO. 1

THE VALUE OF BODY SECTION ROENTGENOGRAPHY (PLANIGRAPHY) FOR THE DEMONSTRATION OF TUMORS, NON-NEOPLASTIC DISEASE AND FOREIGN BODIES IN THE NECK AND CHEST*

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PHILADELPHIA, PENNSYLVANIA

EXPERIENCE obtained with body section roentgenography indicates that this method gives visual information that is not obtained by any other type of roentgen examination. This is especially true when dealing with disease of the respiratory tract, so that it is our routine to do planigraphic examinations whenever ordinary roentgen studies fail to yield adequate information as to the nature and extent of a lesion.

The indications for planigraphy and the results obtained from the application of the method in the neck and chest are set forth in this paper, but a detailed description of our apparatus and a discussion of the underlying principles that govern its construction and use are not included because this information is already available in the literature.[1,3] The present equipment is constructed so that simultaneous longitudinal movements of the roentgen tube and film take place in opposite directions in a straight line with the tube and film moving in planes parallel to each other and to the plane of the body under examination. Although our equipment is not elaborate, it functions smoothly and the planigraphic images are clear-cut.

Anteroposterior planigraphy is invaluable for demonstration of the soft tissues of the neck because it eliminates the superimposed spine shadow that is present on conventional projections of the neck (Fig. 1). Leborgne[7] in 1936, first called attention to the value of "frontal tomography" of the larynx, and since that time it has been used extensively as a diagnostic aid in this region, particularly when dealing with carcinoma. When the disease is moderately or well advanced, there is usually so much distortion of the laryngeal tissues from the carcinoma that it is difficult or impossible to determine the exact extent of the disease and the amount of side-to-side encroachment on the airway unless planigraphy is done. As emphasized in a previous article,[9] when the tumor is situated in or extends into the subglottic region, body section roentgenography gives more information about the extent of the disease than any other single method of examination, including endoscopy (Fig. 2*A*). Some of the other abnormalities demonstrated by frontal planigraphy of the larynx are benign tumor of the larynx, laryngocele and vocal cord paralysis (Figs. 1*B*, 2*B* and 3*A*).

Planigraphy is useful to determine lateral encroachment on the cervical trachea due to extrinsic pressure, as in Hodgkin's disease or carcinoma of the thyroid, and serves a definite need as an indicator of the progress made during conservative and reconstructive treatment of laryngeal and tracheal stenosis, such as is seen following diphtheria, severe streptococcic laryngitis and high tracheotomy (Fig. 3, *A* and *B*). The demonstration of tracheal stenosis in the chest is often unsatisfactory because of the superimposed shadows of the spine and mediastinal structures. If stenosis is due to extrinsic pressure from an aneurysm or tumor, interference with visualization may result from their shadows. These interfering shadows are not recorded on planigraphic roentgenograms of the trachea, so they give much more information than is obtained by conventional roentgen examinations. Lateral planigraphy is combined with anteroposterior studies when the tracheal lumen

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is markedly narrowed by intrinsic disease or if dense masses to either side of the trachea obscure the tracheal shadow (Fig. 3, *C* and *D*).

Another practical application of the method in examination of the neck is found in the localization of opaque foreign bodies in relation to the lateral margins of the air

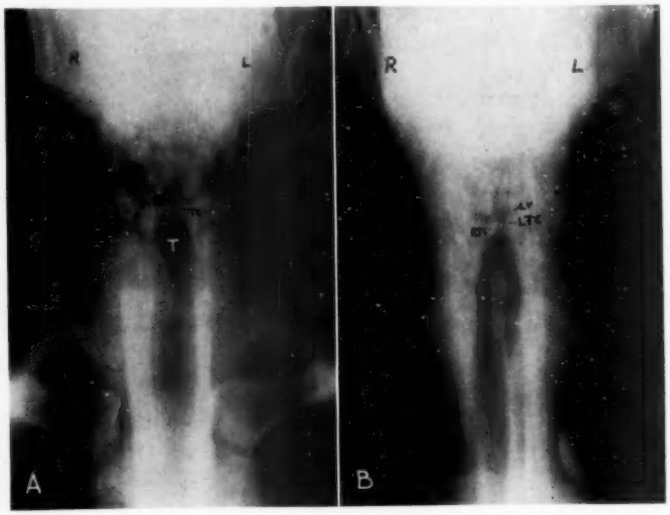

FIG. 1. Planigraphic appearance of normal larynx and vocal cord paralysis. *A*, normal larynx. FC, false cord; V, ventricle; TC, true cord; T, trachea. *B*, left vocal cord paralysis. LTC, paralyzed left true cord is abducted. LV, left ventricle is obliterated. Note asymmetry of lateral margins of airway in subglottic region. RTC, right true cord located to left of usual position in an attempt to approximate paralyzed left true cord. Roentgenoscopy shows unilateral motion of cords.

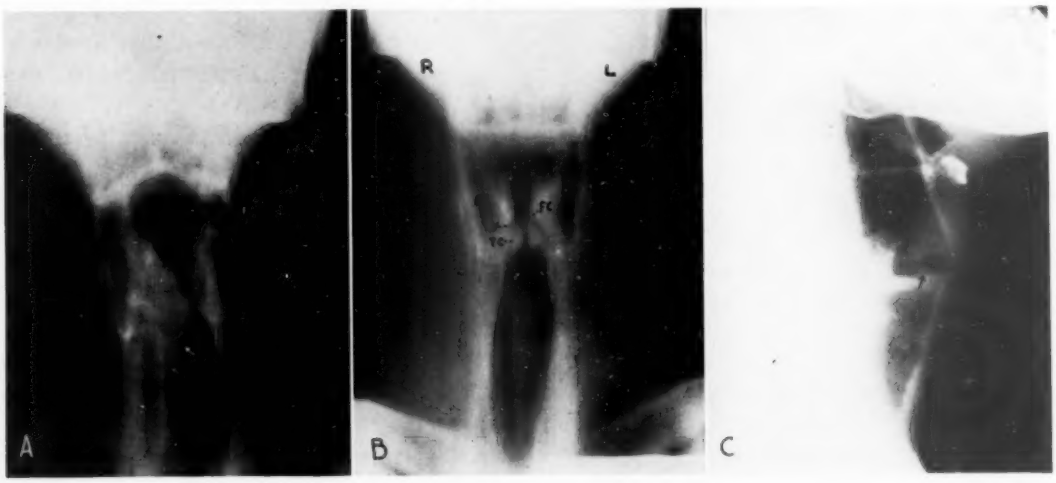

FIG. 2. Anteroposterior planigraphic appearance of benign and malignant tumor of larynx. *A*, carcinoma of right false and true cords with subglottic extension of tumor (indicated by arrows). Airway is narrowed and deviated to left by tumor. *B*, fibroma of right true cord (arrow) partially obliterates ventricle, V. True cord, TC, is thickened. FC, false cord; PS, pyriform sinus; AE, aryepiglottic fold. Lateral projection, *C*, reveals fibroma but planigraphic film is necessary to lateralize tumor.

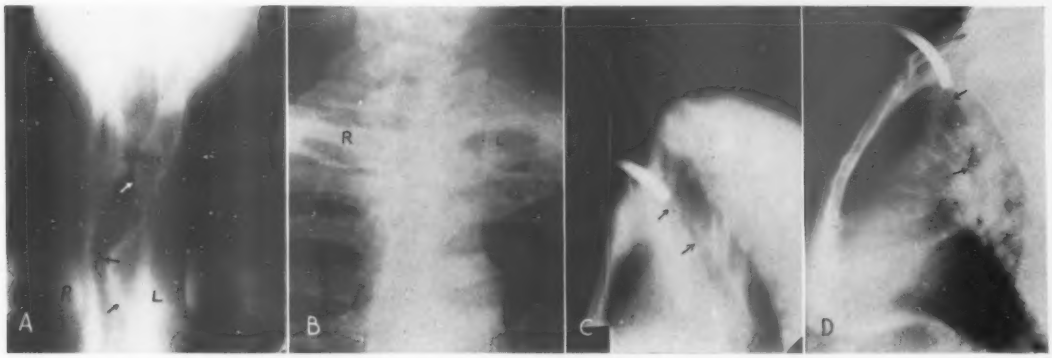

Fig. 3. Tracheal stenosis demonstrated by planigraphy. *A*, deformity of cervical trachea caused by cancer of thyroid. Paralysis of left vocal cord (TC) is secondary to tumor involvement of left recurrent laryngeal nerve. Note change in shape of subglottic area on side of cord paralysis. *B*, conventional film included to show superiority of planigram. *C*, severe tracheal stenosis of "inflammatory origin" visualized by lateral planigraphy. Repeated bronchoscopic biopsies negative for tumor despite rapid progression of disease. *D*, conventional Potter-Bucky lateral film does not show tracheal lumen as well as planigram.

and food passages. Conventional lateral roentgen study is sufficient for localization if the foreign body is in the lumen of either passage because the endoscopist needs to know only its level, but if the foreign body is off to either side, and perhaps partially imbedded in mucosa, accurate localization is necessary in both planes. Equally important to the endoscopist is the information concerning the shape of the foreign body, particularly its cephalic end, that is obtained by anteroposterior planigrams. Nonplanigraphic ventral or dorsal projections are not adequate because the spine shadow interferes with visualization, but dorsal planigraphic projections show the foreign body and its side-to-side relationship no matter whether it is in the air or food passage (Fig. 4). The necessary delay in removal of the foreign body that occurs when an opaque mixture is used for lateralization is obviated by this method of localization.

Foreign bodies in the lungs that are sufficiently dense to cast a shadow only on ventral or dorsal projections but not on lateral projections are localized by body

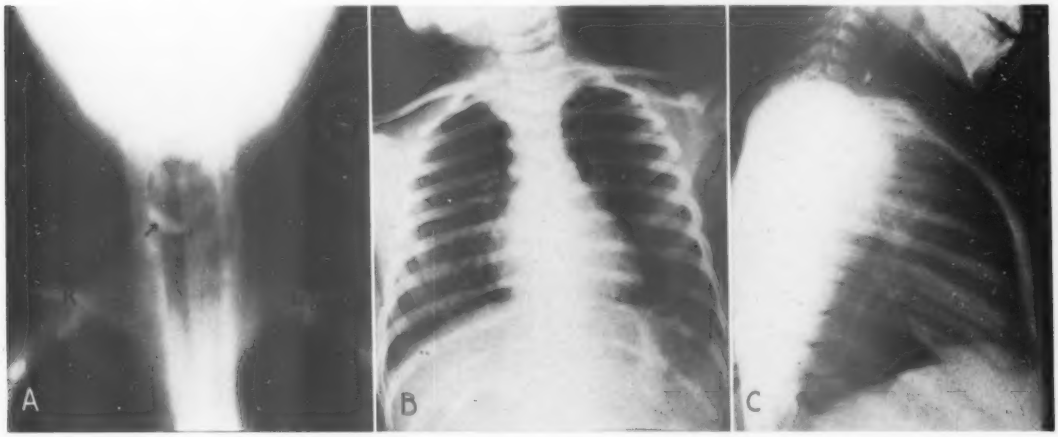

Fig. 4. Demonstration of opaque foreign body in cervical esophagus by anteroposterior planigraphy, *A*. Planigraphic lateralization necessary because foreign body was largely extraluminal and therefore out of range of endoscopic vision. Conventional lateral view, *C*, shows level of foreign body with air in tissues but it could not be demonstrated by an ordinary anteroposterior roentgenogram, *B*.

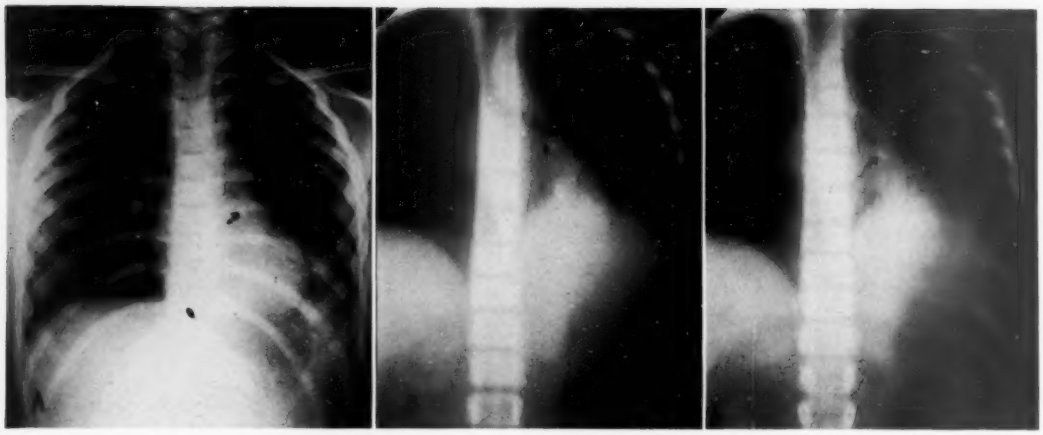

FIG. 5. Localization of foreign body in atelectatic lung by anteroposterior planigraphy. *A*, conventional dorsal projection shows tooth root fragment but it could not be identified on ordinary lateral projection due to foreign body atelectasis. *B*, foreign body visualized by this planigraphic section which also shows a left lower lobe bronchus. *C*, planigraphic section 1 cm. posterior to *B* delineates foreign body better than section *B* but bronchus is not as well demonstrated. This indicates that foreign body is at level 1 cm. posterior to mid-plane of bronchus. Bronchoscopic removal followed this planigraphic localization.

section roentgenograms. Our experience includes accurate localization of a deciduous tooth that could not be visualized by lateral projections due to resultant abnormal density from the foreign body atelectasis. Since the depth of the anteroposterior planigraphic section that showed the foreign body was recorded, it was easy to determine the relation of the tooth to the anterior and posterior aspects of the lung, and thus ascertain which bronchial branch harbored it (Fig. 5). Before this examination it was impossible to locate the foreign body bronchoscopically, but bronchoscopic removal followed this planigraphic localization.

In the chest, body section roentgenography enables recognition of disease processes that cannot be diagnosed by conventional routine studies because, with this special technique, only the shadows produced by the disease are recorded to the exclusion of confusing superimposed shadows such as are produced by a dense layer of

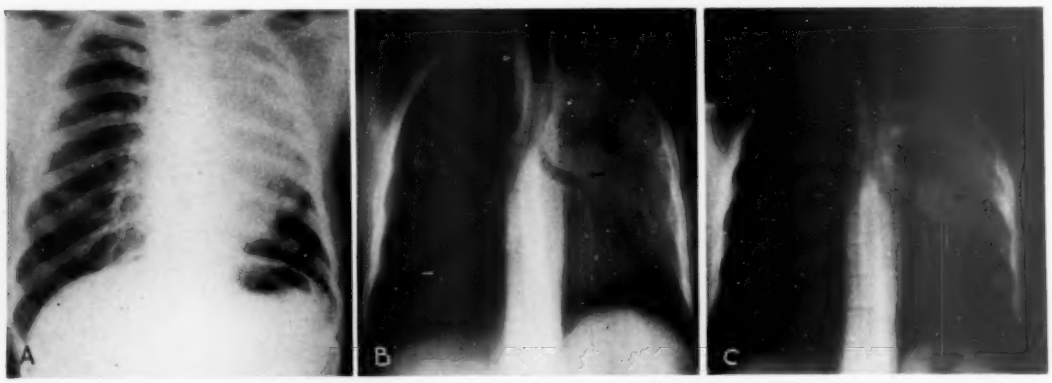

FIG. 6. Bronchial carcinoma delineated by planigraphy despite dense atelectatic lung. *A*, conventional roentgenogram shows atelectasis of left upper lobe but no evidence of tumor. *B*, point of occlusion of bronchial tree clearly demonstrated. Tumor and occlusion indicated by arrows. *C*, section 1 cm. posterior to *B* reveals tumor better than *B* but occlusion is not seen as well. Needle biopsy tissue obtained after planigraphic localization was positive for carcinoma.

pleural fluid or atelectatic lung. In our experience the results are more spectacular with lung tumors and tuberculous cavities than with any other abnormality (Figs. 6 and 7). Not only is the shadow of a tumor differentiated from that produced by surrounding dense lung tissue, but the neoplasm is sharply localized so that aspiration biopsy is feasible (Fig. 6). If the tumor arises in one of the major bronchial divisions, the resultant narrowing or occlusion of the bronchus is demonstrable although the tumor itself may be better visualized on a roentgenogram exposed at slightly different depth than the one that shows the deformed bronchus. Such a finding indicates existence of the major portion of the growth outside of the bronchial lumen (Fig. 6).

Deformity or occlusion of the tracheobronchial tree due to causes other than tumor is made apparent by body section films in cases where conventional roentgenograms are uninformative because of pleural fluid or adjacent dense lung. In one patient, thought to have bronchogenic carcinoma because of chronic cough with expectoration, weight loss and progressive down-hill course, bronchiectasis and suppurative pneumonitis were demonstrated despite a large pleural collection that interfered with previous attempts at roentgen visualization. Bronchial carcinoma was ruled out by planigraphy because none of the roentgenograms showed any evidence of a mass in or about the bronchial tree. At autopsy, this interpretation of the planigraphic findings was verified.

The value of planigraphy to demonstrate tuberculous and non-tuberculous lung cavities has been emphasized in the past by Grossman,[5,6], Chaoul,[4] Bernard,[2] and recently by Moore.[8] Once the usefulness of the method is appreciated, it becomes an indispensable laboratory procedure to the phthisiologist and thoracic surgeon. There are times during the management of pulmonary tuberculosis when the clinical and laboratory findings indicate breakdown of lung tissue without roentgen evidence of either a new focus or change in the area under observation (Fig. 7). This sometimes happens when the disease is apparently controlled by collapse therapy so far as can be judged by conventional roentgen studies. This problem confronted us several times, and, in each instance, previously undemonstrated cavitation was revealed by planigraphy in either the partially collapsed lung or in the opposite lung (Fig. 7). Provided the examination is done thoroughly, with proper technique, negative findings are reliable and therefore the method is as valuable to rule out cavitation as it is to establish the presence of a cavity.

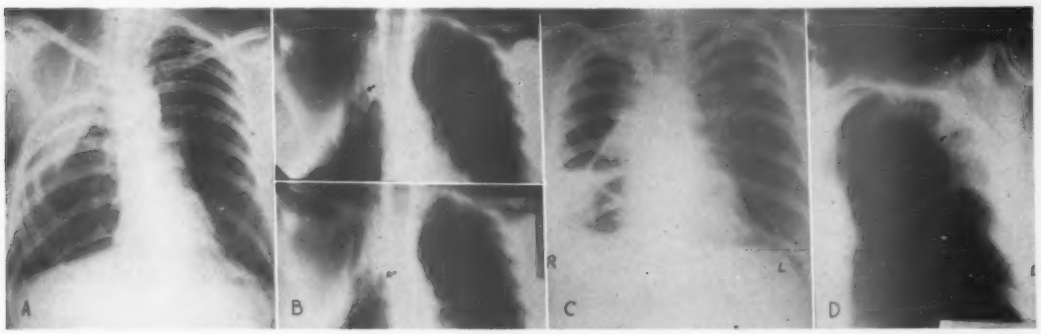

Fig. 7. Tuberculous cavities demonstrated by planigraphy in patients treated by collapse therapy. *A*, lung collapsed by thoracoplasty considered adequate because of non-planigraphic roentgen appearance of chest. *B*, several tuberculous cavities revealed in same "collapsed" lung by planigrams. Planigraphic sections exposed at levels 1 cm. apart. *C*, conventional film shows good collapse of right lung and no evidence of cavitation in left lung. *D*, very large tuberculous cavity demonstrated by planigram in this left lung.

SUMMARY

Body section roentgenography gives visual information that is not obtained by any other type of roentgen examination, particularly in the respiratory tract where indications for its use are more numerous than elsewhere in the body. In the neck, anteroposterior planigraphy is invaluable for the demonstration of the laryngeal and adjacent soft tissues because it eliminates the spine shadow and therefore reveals any change in shape of the airway. It is indispensable to determine the extent and size of a subglottic neoplasm because such a lesion cannot be visualized completely by any other method of examination, including endoscopy. Benign and malignant tumors of the larynx, laryngocele, vocal cord paralysis, laryngeal and tracheal stenosis due to intrinsic or extrinsic disease, are some of the other abnormalities in the neck that are better demonstrated by planigraphy than by conventional roentgen studies. In addition, it enables localization of opaque foreign bodies in relation to the lateral margins of the air and food passages in the neck.

Disease processes in the lung that cannot be visualized by conventional roentgen studies, because of adjacent atelectatic lung, pleural fluid or some other dense tissue, are frequently made apparent by planigraphy because it eliminates such confusing superimposed shadows. The method is particularly valuable to demonstrate lung cavities or tumors that cannot be seen by ordinary roentgen studies and, provided the examination is done thoroughly, planigraphy is as reliable to rule out cavitation or tumor of any appreciable size as it is to establish the presence of either of these two conditions. Tracheal stenosis, bronchiectasis, or distortion of the tracheobronchial tree due to any cause, is made apparent even in the presence of dense neighborhood structures and when indicated, planigraphy aids in localization of opaque foreign bodies in the lung.

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VOL. 47, NO. 1

FRACTURES OF THE PELVIS

WITH SPECIAL REFERENCE TO ASSOCIATED FRACTURES OF THE SACRUM

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THE subject of fractures of the pelvis has been rather widely discussed, and this is particularly true of the treatment and results of the complications of such fractures. A review of much of the recent literature, however, reveals an interesting lack of serious consideration of the high incidence of fractures of and about the sacrum, associated with fractures of the pelvic ring elsewhere, chiefly anteriorly and usually involving the obturator foramen. It is true that most authorities recognize the possibility and even the probability of such injuries, but the percentage of posterior pelvic fractures in published reports is rather low when compared to cases of this type to be considered in this study. Recognition of these fractures is not a recent innovation, evidenced by the fact that some of them, the double horizontal fracture of both the anterior and posterior aspects of the pelvic ring, bear a well known and generally used title, namely the Malgaigne fracture. Numerous textbooks also mention them and although some report only the rarity of sacral fractures, others very definitely warn of the frequency with which they may be overlooked. A personal interest in this phase of the subject was created by a verbal report of a radiologist, Dr. E. R. Crowder, who stated that he had collected a series of 23 fractures of the sacrum, with or without other pelvic fractures. Many of these, he felt, would undoubtedly have escaped detection had he not deliberately studied the sacrum in every case in which there was evidence of pelvic injury. With this stimulation a study of all pelvic fractures entering the hospital was begun and an unusually large percentage of fractures of the pelvic ring posteriorly was discovered. Needless to say, the practice of a thorough, careful study of the sacrum has been adopted as a routine in every case of pelvic injury. In addition, it was noted that technically clear roentgenograms were absolutely essential to a complete diagnosis in many of the cases. Roentgenograms made with a bedside unit often failed to reveal any evidence of many of the fractures of the sacrum, while later roentgenograms made with the aid of a Potter-Bucky diaphragm showed very definitely that such injuries existed. Hence it is a routine practice to recheck every doubtful case, at the earliest possible moment, with roentgenograms made under more favorable conditions, in the roentgen department.

For this report 96 fractures of the pelvis seen in the five year period between January 1, 1935, and December 31, 1939, have been studied. Because most isolated fractures of the ilium and of the acetabulum do not ordinarily break through the pelvic ring they have been excluded from this survey. Two acetabular fractures, with central dislocation of the hip, have been included, however, because both resulted in complete fractures of the pelvic ring and both were accompanied by fractures of the sacrum. Isolated fractures of the sacrum have been included in this report because the study was primarily undertaken to show that these fractures occur rather frequently. The youngest patient with a pelvic fracture in this series was a three year old girl who was hit by an automobile at a street intersection, the oldest was a woman, aged ninety-one, who fell down the stairs of her home. The child received fractures of the left ilium, left side of the sacrum, and a sacroiliac separation, while the oldest patient received a complete fracture of the right obturator ring, involving the rami of the pubis. The average age of all the patients under observation was thirty-two and a

half years. Sex incidence in the series showed 63 females and 33 males, a reversal of the figures generally noted in most published reports.

A study of Table 1 reveals clearly that the fractures considered in this series were generally the result of violent accidents, with automobiles largely responsible for the most severe injuries. Seventy-nine of the 96 fractures were directly attributed to the automobile and 3 other fractures were accounted for by trains and an aeroplane crash, making 82 of the 96 fractures resulting from great violence. Fourteen other fractures resulted from what might be called less trivial accidents; accidents sufficiently violent, however, to produce pelvic fractures.

TABLE I

TYPES OF ACCIDENTS RESPONSIBLE FOR THE PELVIC FRACTURES IN THE FIVE YEARS BETWEEN JANUARY 1, 1935 AND DECEMBER 31, 1939

Fractures resulting from automobile accidents	79
Automobile collisions	59
Pedestrians struck by automobiles	12
Overturning car struck child	1
Skidding car overturned injuring driver	1
Car hit tree	1
Car hit by train	3
Bicycles hit by car	2
Causes other than automobiles	17
Falls	12
Runaway horse	1
Toboggan slide accident	1
Rolled between freight cars	1
Hit by a train	1
Aeroplane crash	1

CAUSE OF PELVIC FRACTURES

The sudden impact of two automobiles, one or both of which were, in most cases, travelling at a high rate of speed, creates a tremendous force, much of which is transmitted rather directly to and is to a great extent absorbed by the passengers. Explosive pelvic fractures are undoubtedly caused by this great force, resulting frequently in fractures of two sides of the pelvic ring, one of which is usually complete. A study of the cases of pelvic fractures resulting from automobile collisions reveals that many of the fractures occurred in persons who were riding in crowded cars in which the seats were well filled. Further, the occurrence of two or more cases of pelvic fractures in a single accident, in passengers riding in the same seat, introduces another consideration, namely the primary force of the impact, plus the additional force applied when the weight of the body of one passenger is unexpectedly thrown against another. The passenger on the side of contact receives not only the full force of the impact but the additional force of the weight of his fellow passengers. This great force results in pressure applied mainly to the sides of the pelvis, since three passengers so riding usually completely fill the space allotted to the seat. The person riding on the side of the impact is thus squeezed severely by his fellow passengers and the rigid side of the car, and the passenger in the middle receives a similar squeeze between the other passengers. A complete analysis of all 96 fractures, relative to the position of the injured passenger in the car was, of course, impossible. A study of three accidents, however, resulting in pelvic fractures in seven passengers shows: (1) all three passengers riding in the rear seat of a car struck by another received pelvic fractures; (2) two of three passengers riding in a single seat of a car involved in a collision received pelvic fractures, the passenger on the side away from the impact being the one to escape serious injury; (3) two passengers riding in the single seat of a small coupé, struck by a larger car, were found to have pelvic fractures. The fact that so many persons riding in crowded cars, involved in collisions, usually escape the serious injury sustained by another passenger is probably

TABLE II

SITES OF FRACTURES OF THE PELVIS

Total number of cases	96
Obturator foramen fractures	86
Unilateral obturator ring fracture	58
Bilateral obturator ring fracture	28
Complete fracture of the acetabulum	2
Posterior pelvic fractures	67
Isolated sacral fractures	8

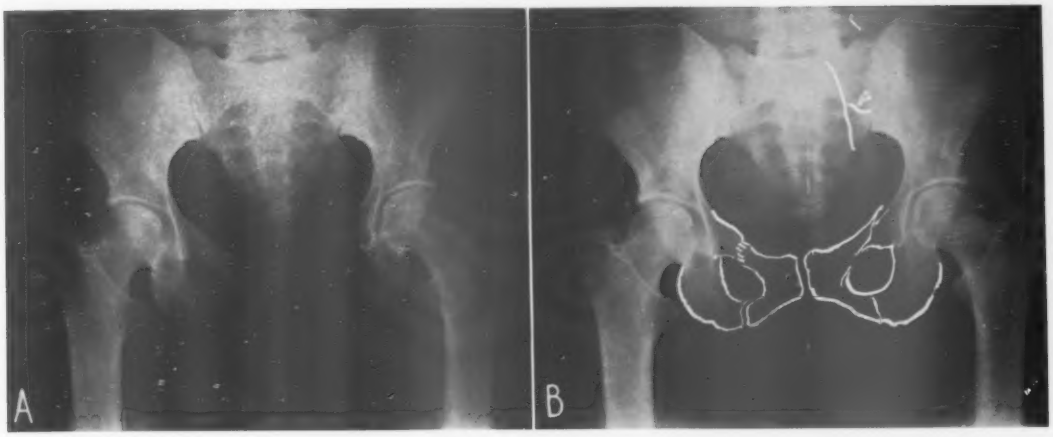

Fig. 1, *A* and *B*. Bilateral obturator ring fractures, with a linear fracture of the wing of the sacrum on the left side.

explained by a lessening of the force on those individuals resulting from personal resistancce, relaxed states or to change in position during the accident, shifting the pelvis from the point of greatest force. With this consideration of the forces applied, a very casual analysis of most pelvic fractures in this series indicates that nearly all of the complete fractures of the pelvic ring were explosive and of the contrecoup type, that is, the result of exceptional stress with strain to the explosive point, which usually occurs at the weakest part of the pelvic ring. Thus in most of these cases the fracture encountered most frequently was one involving the obturator ring either through the pubic rami or through a ramus of the pubis and a ramus of the ischium. The double fracture of the obturator foramen is due to the near impossibility of completely breaking a rigid ring at a single point with an explosive force. This also explains the reasoning behind the idea that a fracture of the pelvic ring anteriorly may be accompanied by a fracture of the ring elsewhere, usually posteriorly. True the pelvic ring is not entirely rigid, but the rigidity is sufficient to apply the rule in many cases, thus accounting for the relatively large number of these fractures that do occur.

Fig. 2, *A* and *B*. Bilateral obturator ring fractures, with a fracture of the wing of the sacrum on the right side. Upper edge of one sacral foramen distorted by fracture.

SITE OF PELVIC FRACTURES

Of the total of 96 fractures of the pelvis, the obturator foramen was involved in 86. These fractures involved both pubic rami or one ramus of the pubis and one of the ischium. Bilateral obturator ring fractures were encountered in 28 patients, leaving 58 in whom unilateral obturator ring involvement was noted.

Fractures of the pelvic ring posteriorly were seen in 67 of the patients. A further analysis of these fractures is shown in Table III.

TABLE III

SITES OF POSTERIOR PELVIC FRACTURES

Total posterior pelvic fractures	67
Fractures of the sacrum	42
Sacral fractures with sacroiliac separation	11
Fractures of the sacrum and ilium	2
Ilium fractures with sacroiliac separation	8
Complete pelvic ring fractures through the ilium	2
Sacroiliac separation without apparent fracture	2

The fractures of the anterior portion of the pelvic ring were usually recognized easily; the posterior fractures, however, were in many cases found only after careful and often minute inspection of the roentgenograms. Close study of the sacral bodies, the wings of the sacrum, and more particularly the sacral foramina, gave clues leading to the discovery of many of the more obscure fractures. Buckling of one edge of a single sacral foramen, similar to that seen in the periosteal bulge of a torus fracture of the radius, proved of great value in locating some of the fainter lines of fracture. Of the posterior pelvic fractures, 65 were found to involve the sacrum or the sacroiliac synchondrosis, alone or in association with fractures of the ilium, or 70 per cent of the total cases. Isolated fractures of the sacrum were seen in 8 patients, or 8 per cent of the total number. The incidence of posterior pelvic fractures in the literature of the past few years is very low when compared to that cited above, some giving as low as 5 per cent, others as high as 30 per cent. This great variance in percentage is undoubtedly due to several factors: first, the fact that most of the cases considered in this study were the result of great violence, while many of the other reported series listed causes of lesser severity, hence fractures of lesser extent. Secondly, most of the other series reviewed included all fractures of the pelvis, whether or not they in any way involved the pelvic ring, while in this study these isolated fractures were eliminated. Other reasons for the difference may be accounted for by a failure to study the sacrum more carefully, and dependence in some instances on a single film which may

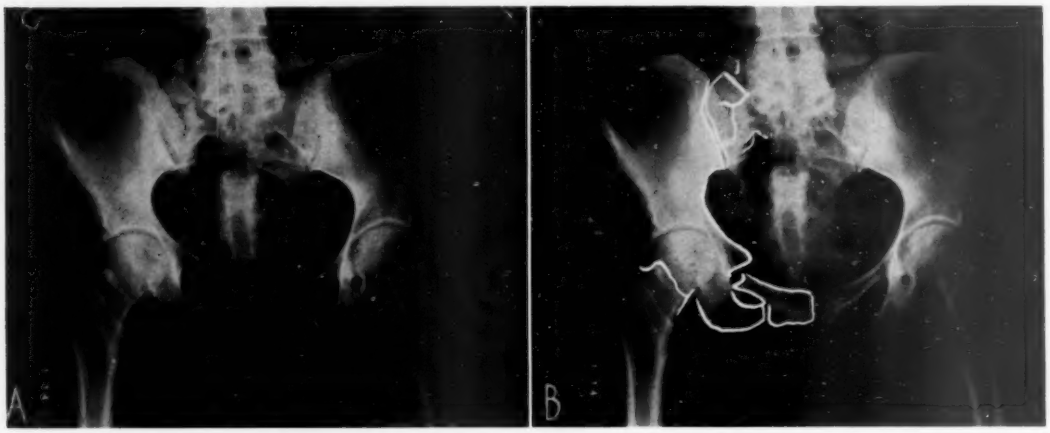

FIG. 3, *A* and *B*. Old fracture of the right obturator foramen, right femoral neck, fifth lumbar transverse process on the right side and clearly demonstrated comminuted fracture of the wing of the sacrum on the right side.

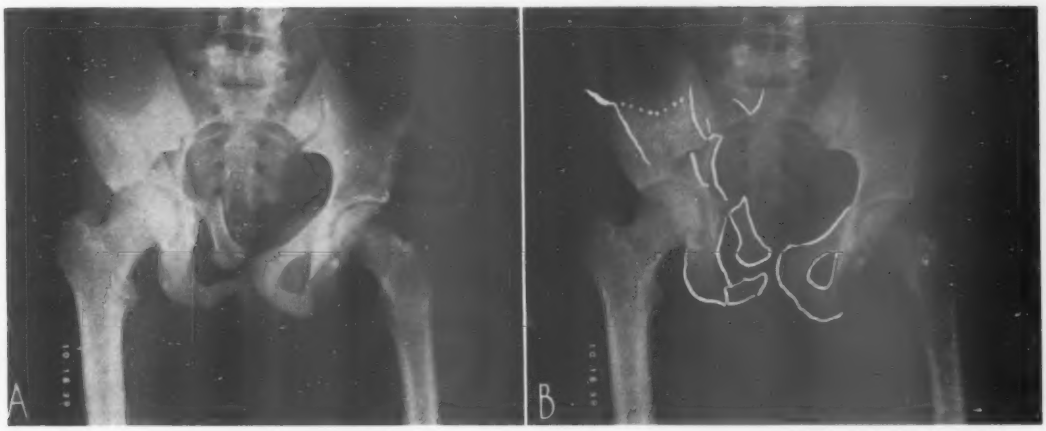

Fig. 4, *A* and *B*. Extensive fractures of the right side of the pelvis, including the right obturator foramen, wing of the right ilium and right side of sacrum adjacent to the synchondrosis. Marked displacement.

have lacked sufficient detail to show some of the linear fractures. Many of the patients do not complain particularly about pain over the region of the fracture because of more severe pain elsewhere due to other injuries, and thus, in some instances, fail to draw attention to the lower back as a possible site of injury.

One may question the importance of searching for fractures, which apparently are so insignificant that they may completely escape detection. The best answer to such a query is that every fracture, regardless of its location or seriousness should whenever possible, be diagnosed, thus to enable proper consideration and treatment of all the injured parts and not only the more obvious injuries that may be present. True, the treatment of such fractures is, in most cases, well cared for by routine treatment of the other pelvic fractures. Knowledge of such fractures may, in many patients, give information relative to low back pains suffered by these patients later in life; certainly such a possibility should be considered when one stops to reflect on the difficulties encountered with routine cases of low back pain. Further, the possibility of

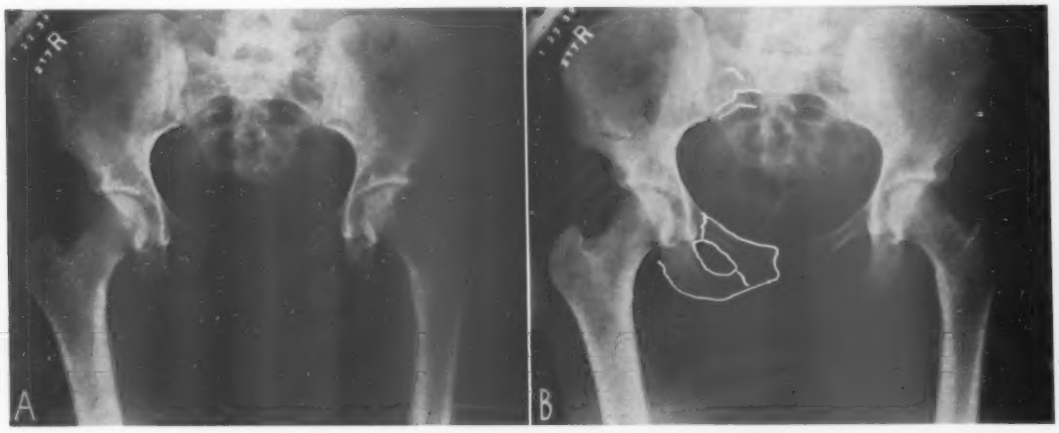

Fig. 5, *A* and *B*. Double, incomplete fractures of the right obturator foramen and right side of the sacrum, with buckling of the edges of the sacral foramina.

Fig. 6. Fractures of both obturator foramina and fracture of the left side of the sacrum near the sacroiliac joint.

nerve injury should also be considered, although none of any consequence were met with in this series.

COMPLICATIONS

Serious complications of pelvic fractures, or of the injuries which produced them, were of sufficient importance to cause difficulty in the treatment of 40 patients. The complication most frequently encountered, aside from the primary shock of the injury, was fractures elsewhere, occurring in 28 patients. The fractures involved various bones, the skull being fractured in 6 patients, fractures of the hip in 5, with associated dislocation in 2, and one patient alone sustained a fracture of the skull, fractures of six ribs, fracture of the shaft of the humerus, and a fracture of the lower leg on the side of the pelvic fracture. Some of the fracture complications caused greater difficulty in handling than the apparently more severe fracture of the pelvis. Injuries

Fig. 7. Multiple fractures of the right obturator foramen and the right side of the sacrum laterally.

Fig. 8. Double fracture of the right obturator foramen with fracture of the wing of the sacrum on the right side, showing buckling of the edges of the lower sacral foramina.

to the urinary tract were next in frequence on the list of complications, being seen 7 times. These included rupture of the urinary bladder in 4 patients, rupture of the urethra in 1, and rupture of the kidney in 2. Undoubtedly many less severe urinary tract injuries occurred, but they could not be definitely determined by generally accepted diagnostic procedures; however, urine reports showed many red blood cells to open evidence of hemorrhage in 42 patients. The urine reports of the other 54 patients showed negative or few red cells. Those patients with large amounts of blood in the urine were considered to have urinary

tract injuries even though such injuries could not be demonstrated. Pneumonia was encountered in 2 patients, pyelitis in 1, paralytic ileus in 1, and dementia praecox in 1 of the pneumonia patients.

TREATMENT

The problem in this paper was primarily a diagnostic one, but such a treatise would not be complete without at least some consideration of the treatment of the fractures. The cases were handled by forty-two different physicians, under the guidance of a fracture committee. In spite of the great number of physicians involved, many of whom had charge of only one such patient during the five year period, the treatment was rather uniform. Most of the patients were treated by rest in a fracture bed or other bed with stiff mattress, with immobilization by sand bags or a canvas band. Attempts to reduce displacement of the fragments were only made when such displacement was marked and when it was felt that the position might injure adjacent organs or interfere with comfortable existence. Body casts were used in some patients usually to enable the patient to be removed from the hospital before completion of the treatment, rather than in an attempt to immobilize the pelvis. Leg extension was utilized in a few cases to reduce marked displacement or to prevent displacement from occurring.

Fig. 9. Bilateral, incomplete fractures of the obturator foramina and the right side of the sacrum laterally.

Fig. 10 Fractures of the left obturator foramen and of the left side of the sacrum.

RESULTS

Recovery was nearly complete in 48 patients during the hospital stay, 15 patients being allowed to walk before final discharge and 33 patients were allowed the use of a wheel chair during the last days of the period of hospitalization. Thirty-seven of the patients left the hospital in ambulances; many of these were moved to shorten the hospitalization period. This was necessary in some because of economic difficulties and in others because of a desire to rest at home. None, however, left the hospital unless the patient and the attending physician were in accord on the opinion that such fractures without serious complications could be well treated at home. Four of the patients still remain in the hospital. Seven of the 96 patients died, 4 as a result of urinary tract complications, 1 of cardiac disease, 1 of a pulmonary embolus, and 1 of pneumonia. Of the urinary tract complication deaths, 3 were in patients who had sustained ruptured urinary bladders. Death in these occurred on the second, sixth, and eighth days of hospitalization. One patient with a ruptured urethra died on the eleventh day. The cardiac death occurred on the fourth day and a pulmonary embolus death occurred

on the eighth day. One patient died a month after injury of a streptococcic pneumonia, although his injuries were progressing satisfactorily. This patient had the additional complication of a dementia praecox.

CONCLUSIONS

Ninety-six fractures of the pelvis, resulting for the most part from great violence, were seen and studied in a period of five years. Eighty-six of these sustained fractures involving the obturator foramen and 67 had fractures of the pelvic ring posteriorly. The sacrum or sacroiliac synchondrosis were involved in 65 of the patients, alone or in association with other pelvic fractures. This large number of fractures of and about the sacrum is undoubtedly the result of the great violence involved in their production. Such fractures were apparently very rare before the introduction of high speed automobiles and good roads, but today are rather commonly seen in most hospitals that receive patients injured in these accidents. Closer study of the sacrum, and better detail in the roentgenograms will undoubtedly result in the discovery of many more of these fractures.

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TIME OF APPEARANCE AND FUSION OF OSSIFICATION CENTERS AS OBSERVED BY ROENTGENOGRAPHIC METHODS

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INTRODUCTION

A PERUSAL of the various anatomical authorities shows a very striking discrepancy regarding the ages at which the different ossification centers appear and the various epiphyses first become calcified and fuse with their respective diaphyses. In former years, the only method of examination of the epiphyses was to study the dead subject, but opportunities of doing this on an extensive scale were, and still are, very rare, and in any case it is not always a simple process to determine by ordinary inspection whether an epiphysis has been present or not. Moreover, with the exception of a study by Stevenson on a rather limited number of dried skeletons, no such attempt appears to have been made. However, it is by means of a roentgenographic examination that not only are the ossific centers more clearly and more certainly demonstrable in most cases in the living subject, but a larger series, with exact information concerning the respective ages can be more easily studied and compared.

It has been felt that a much more accurate and authoritative account of the dates of appearance and fusion of ossific centers than is at present available would be of very great value for comparative purposes, especially in investigations concerning racial differences, effect of environment and climate, and for clinical and medicolegal purposes. It is hoped that this may stimulate further research in various directions, and such research will have a value in direct proportion to the accuracy with which the observations are recorded.

ALTERED TIME OF APPEARANCES OF OSSIFIC CENTERS IN ENDOCRINE DISTURBANCE

Only recently has the great importance of the study of the time of appearance of the ossific centers been appreciated in the study of endocrine disturbance, more particularly by Shelton, while Clark has shown the effects of such conditions as hypothyroidism, macrogenitosomia, gigantism, etc., and illustrates in a striking manner with the aid of roentgenograms (Fig. 1) the appearances of the epiphyses both before and after endocrine therapy. He is, however, under the quite unjustified impression that the study of the development of the epiphyses by roentgenological means has been fairly exhaustive and quotes some of the authorities which are mentioned and criticized below, and also includes reference to a somewhat inadequate chart by Camp and Cilley embodying the "opinions" of numerous authorities from the textbooks not only prevailing at the time, but even now still to be found in the latest editions of such works. In rare instances only is it possible to trace the source of the authors' information in such textbooks and it appears that the periods are founded rather on vague guesses than upon careful investigation.

INFLUENCE OF DIET AND HEALTH

Francis studied particularly selected groups of children, 25 each males and females in each of four groups, namely (*a*) breast fed, (*b*) not breast fed, (*c*) those with gastrointestinal disturbance and (*d*) those dead as the result of severe illness. In this

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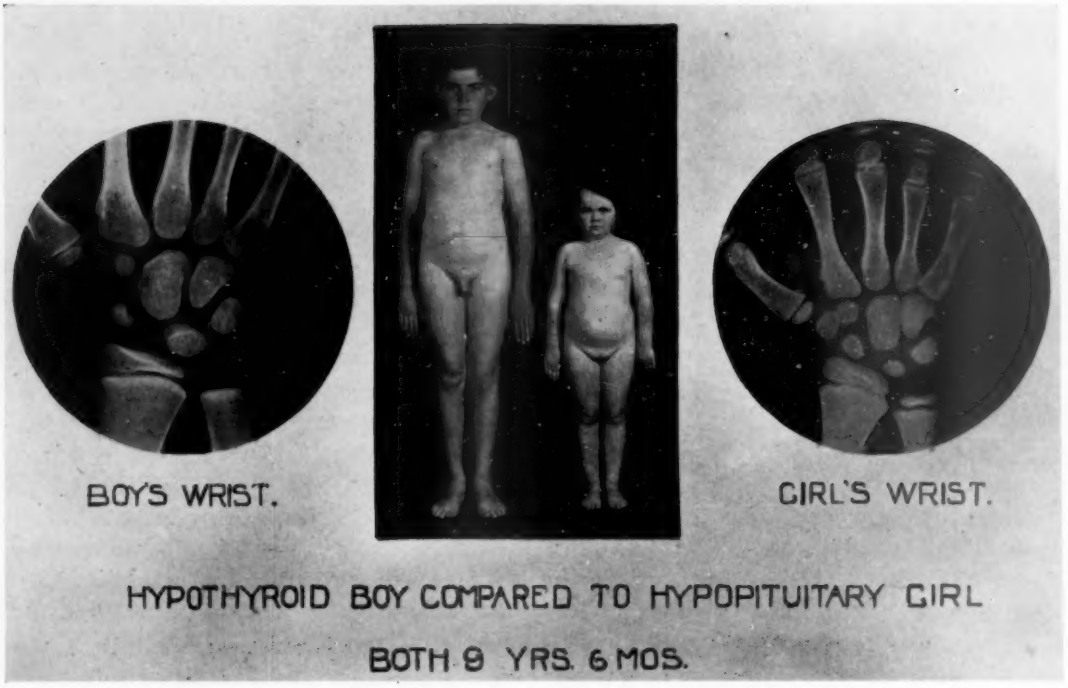

FIG. 1. Hypothyroid boy compared to hypopituitary girl. Both aged nine years six months. (Courtesy of Dr. D. M. Clark, Santa Barbara, California.)

comparative study of the degree of epiphyseal ossification in infancy under varying conditions of diet and health, he came to the very important conclusion that "Epiphysial ossification is a more delicate objective indicator of constitutional health than is progress in height or weight," and that "severe or prolonged illness holds back general progress, but epiphysial ossification shows the greatest retardation."

Similarly other influences, especially nutritional and general pathological disturbances exert a considerable effect on these centers. By careful study of the epiphyseal centers, further research is bound to indicate various incipient pathological states at a much earlier stage than hitherto.

WORK OF OTHER INVESTIGATORS

I can nowhere find accurate statistics actually based on the number of subjects examined with the exception of Galstaun, Sidhom and Derry, Pryor, Menees and Holly and Adair and Scammon, and more recently by Francis and Werle, and also by Hill. It should be pointed out that no reliance should be placed on opinions or data which are not based on careful roentgenological observations.

Galstaun presented the results of investigation of about 100 Hindu and Anglo-Indian girls aged 13 to 19 years, the work being limited to the regions of the elbow, wrist and hand. His figures have been made use of for the purpose of comparison, but these show no very great disparity with the series presented here.

Sidhom and Derry investigated the union of some of the epiphyses of the upper limb in over 400 Egyptian boys, mostly between the ages of 14 and 20, being, like Pryor, particularly accurate in recording their ages. The boys were especially examined for the purpose of their research. As compared with boys in the Australian series, the majority were fused at the same age in the case of the medial epicondyle and of both extremities of the radius, a year earlier for the lower conjoint epiphysis of the humerus, distal epiphysis of the ulna and

for the first metacarpal, and two years earlier for the distal phalanx of the thumb. With regard to the extremes, there were instances of both earlier and later fusions in the Egyptian series.

The work of Pryor, however, is of monumental importance, for, as the result of a study of 554 roentgenograms of the hands of children from 3 months to 14 years of age, he came to the following striking conclusion: "The bones of the female ossify in advance of the male. This is measured at first by days, then months, then years," a conclusion which is abundantly confirmed elsewhere. Moreover, he has carried his research further and, in studying the roentgenograms of 140 fetuses from ten and a half to 38 weeks of age, 71 being male and 69 female, reached the very unexpected result that "in the embryo and throughout intrauterine life, progressing from days to weeks and months." Such advances apparently take place even before external sex differentiation can be determined.

Although abundant evidence of the advance in females is present from the period after birth, Pryor does not give any data regarding such priority from "the earliest developments of centers of ossification." In the series of fetuses which I examined the priority of the female is clearly noted and is referred to in the text under the appropriate headings.

Menees and Holly have examined 500 films taken of infants within 48 hours after birth, all over 2 kg. in weight and 39 cm. in length with a menstrual age of at least 255 days. Of these, 263 were males and 237 females, and included 2 negroes. The centers for the head of the humerus, coracoid, capitate, hamate, head of femur, distal epiphysis of femur, proximal epiphysis of tibia, cuboid, and third cuneiform were especially noted.

Adair and Scammon have also examined a smaller series of 45 females and 55 males within 48 hours after birth, the females varying in weight from 2,185 to 4,440 grams and in length from 43 to 54 cm., the males 2,080 to 5,060 gm. and from 42 to 54 cm. in length. The examination was confined to the distal femoral and proximal tibial epiphyses, cuboid, capitate and hamate.

Stevenson studied the periods of fusion only in 110 skeletons aged between 15 and 28 including 83 from 15 to 25 years of age. He makes the following extraordinary criticism of the roentgen examination, which is quite unjustified: "The recent assertion of Pryor, made without any confirmatory evidence, that the epiphyses in the female unite 3 to 4 years earlier than in the male receive no support in this work. On the contrary, the reader is warned against relying too confidently upon the apparent condition of union or non-union in the radiogram which is merely a confusing medley of shadows." However, as Stevenson has not separated the skeletons of the females from those of the males, his work is not of value for the purpose of comparison with the Australian series, and in any case, of the 110 subjects between 15 and 28, but 20 are female, of whom 18 are between the ages of 15 and 25. Many of the conclusions arrived at can be readily challenged, particularly the alleged constancy of behavior of the epiphyses with regard to the ages of fusion. His work adds no information of value in the studies of epiphyses, but is included as a sample of the poor kind of research upon which our previous knowledge rested.

Borovansky and Hnévkovský investigated the bones of both the upper and lower extremities of 352 boys of all ages up to 19 years, the roentgenograms being especially made for the purpose of the research. Even with this limited material, all of boys from Prague, charts representing the periods of ossification are shown, although the actual number at each age is not given. The work, however, is valuable, inasmuch as many measurements of the size of the various epiphyses at different ages are given.

Paterson has investigated about 1,000 roentgenograms and roughly tabulated his results, although he gives no actual statistical figures.

Davies and Parsons have described the

appearances of epiphyses as seen in roentgenograms, giving detailed information of the ages when these were seen, but no numerical data from which the relative frequency can be ascertained are given. Unfortunately, the sexes of the individual examples are more frequently omitted than inserted in the text.

An immense advance in method of investigation has been initiated by Francis and Werle who examined 307 male and 315 female white American children of the "economically stable" class, all selected on account of their normal health, of "good heritage, favorable environment and abundance of protective foods," and under the supervision of a pediatrician. Roentgen examinations were undertaken at 3, 6, 9, and 12 months and thence every 6 months until the age of 5 years, the maximum number in any age group being 104 girls and 96 boys, the minimum 55 girls and 39 boys. Despite the fact that these examinations were only carried out at not less than 3 month intervals, the ages of appearance of centers is given at various intermediate intervals such as 2, 7, monthly from 10 to 16 months, etc. Moreover, it is stated that in compiling standard tables for the age and sequence of appearance of ossification centers, the age given was that shown when 20 per cent rather than 50 per cent were present, but the reason for this is not apparent. Possibly they regard the earliest age as the optimum. However, it is frequently stressed that delay in the appearance may be caused by such disturbance as illness, endocrine dysfunction, malnutrition, etc., and no doubt this is exceedingly important and accordingly, in their opinion, conclusions of normality based on examination of hospital patients is fallacious.

Although the use of roentgenological examination has been practiced throughout the world for well over 44 years, it is a remarkable fact, that despite the millions of exposures which must have been made in subjects of all ages and in all regions of the body, no really comprehensive survey of the osseous development has even been attempted. There are some regions, more particularly the vertebrae, which have scarcely been touched, and surely it is not creditable either to the roentgenologists or to the anatomists that everywhere in the literature one still finds the same prevailing condition of hopeless confusion, inaccuracies and inconsistency as were present before Roentgen made his great discovery. All the work listed above is quite limited in scope and to a limited number of joints only, and nowhere is there sufficient quantitative information to justify the establishment of any percentage computation, much less the charts which have appeared and still continue to appear in a number of instances.

That recent publications still continue to ignore the evidence produced by more precise investigation is shown by the Tables of Ossification given by Appleton, Hamilton and Tchaperoff, where, for instance, the union of the femoral head is given as 18 to 20 years, yet in the majority these are fused at the age of 14 in girls and 17 in boys. This table shows fusion of the acromial epiphysis as well as the epiphyses for the tuber ischii and iliac crest at the 25th year although in my series, the acromion is shown to be fused in the majority of both sexes at the age of 17 and the tuber ischii and iliac crest at the age of 21, the latter at 20 in females.

MATERIAL EXAMINED

The subjects of this examination were mostly hospital patients, practically all of whom are of European descent, and as nutritional disease such as rickets, scurvy, etc., are not of great frequency in Australia, the error from including such possible conditions is not considerable. To avoid duplicating details of the same subjects, and to assist in checking off age and sex particulars, the names of the individuals and serial numbers of the films were also recorded. Where possible, the actual date of birth of the subject was ascertained, so that the age to the month is given. In the earliest series, this was not done and in these cases the ages are given in years only. Notes are

made only of such centers, the presence or absence of which could be definitely established, and all others, that is those about which there is any doubt at all, are excluded from the records. The majority of this material was obtained from the Prince Henry Hospital, Melbourne.

In addition to the above, a series of about 50 fetuses of varying sizes from 30 to 334 mm. (8½ to 38 weeks) has been examined. As it is impossible to ascertain the exact ages of these, the lengths only are to be considered as accurate, but the ages in weeks have been roughly estimated according to the investigations made by Keibel and Mall and are inserted in parentheses. (One specimen measuring 32.5 mm., however, was aborted 49 days after a single coitus.) The great bulk of material from which these observations were made was obtained from the Women's Hospital, Melbourne, and I am indebted to their radiologist, Dr. Colin MacDonald and to the Medical Staff generally for much valuable assistance.

In 2 only of the series was air found to be present in the lungs, both in females of 298 and 315 mm. in length (33½ and 36 weeks) respectively, although the lungs were airless in 5 female and 6 male fetuses of a length of 294 mm. (33 weeks) or longer. Air was likewise present in the stomachs of both of the former female fetuses as well as in those of 11 other fetuses of which 5 were female and 5 male of various sizes, the smallest being a male of 147 mm. (18 weeks) and a female of 205 mm. (23 weeks), in none of which had breathing commenced as shown by the absence of air in the lungs. It is believed that the air is swallowed and it is consequently inferred that the fetus was living at the moment of birth (Fig. 2). That the gas is not due to putrefactive processes is indicated by the fact that the fetuses when examined were fresh, the stomach being always filled before any part of the intestines and that no fetus smaller than 147 mm. (18 weeks) showed the presence of gas in the stomach. One can therefore infer that the process of swallowing air precedes (probably invariably) that of breathing, and that many fetuses (11 in this series) swallow air, even when through some reason or other they are unable to breathe, although it is possible that the manipulative attempts to force the newborn child to breathe merely causes it to swallow air but it seems unlikely that such an attempt would be made on a fetus as small as 147 mm. (18 weeks) in length.

Fig. 2. Female, 304 mm. (34 weeks). Although there is no air in lungs or intestines, air is present in the stomach. Although no breathing has taken place, fetus has swallowed air, which is evidently not due to putrefaction.

Presentation of Results

The ideal method of presenting the results of such an inquiry would be by means of graphs, but the material available is not nearly sufficient for the purpose, although Stevenson prepared graphs for a very much smaller series. To give percentages, even roughly, where in no instance are there 100 subjects in any age group is likewise objectionable, although authors, notably Paterson, have done so. Many such percentage computations must be sheer guesswork and appear to have been made even

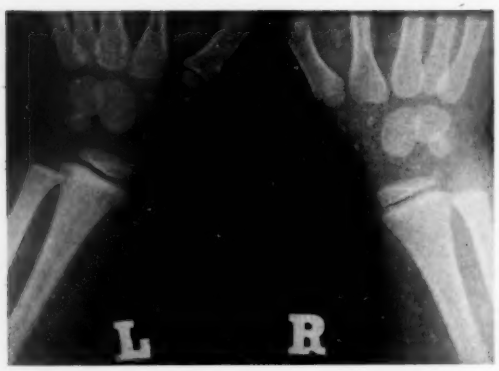

FIG. 3. Male, aged six years eleven months. Multangulum majus is well marked on left but completely absent on right; lunate just appeared on right, but no trace on left. (Courtesy of *Journal of Anatomy*.)

when less than a dozen subjects were under review. The only honest, and it is thought the best, method is to give the actual figures in each age group, and this has been done. Later on, should a vastly larger series be studied, percentages and graphs may be given with confidence as to their relative accuracy.

Stevenson and Paterson have both summarized in considerable detail the ages of appearance and fusion of the different epiphyses as given by numerous authors. Although this is very useful as serving to illustrate the various discrepancies, a repetition of such lists would otherwise serve no useful purpose, and it would be better to discard all data except those based upon actual statistics, for attention has already been drawn to the confusion still existing everywhere in the literature.

With regard to the various descriptions which follow, the following points with reference to each sex have been specially noted:

(a) Ages of youngest subjects in whom ossific centers in question were found to be present.

(b) Ages at which in at least half of the individuals centers were found to be present.

(c) Ages of oldest subjects in whom epiphyses were found to be fused with the diaphyses.

(d) Ages of youngest subjects in whom epiphyses were found to be fused with the diaphyses.

(e) Ages at which in at least half of the individuals epiphyses were found to be fused.

(f) Ages of oldest subjects in whom epiphyses were found to be fused with the diaphyses.

The only ages given are those at which there are found to be variations. At other ages, the centers have been found to be either all present or all absent.

RIGHT AND LEFT SIDES

Though classifications have been made regarding the sex, and notes have likewise been taken with respect to the sides, whether right or left, any classification regarding the two sides would considerably burden this work, but as yet no detailed study has been made concerning the possibility of any appreciable difference of one side as compared with the other. Moreover, it is doubtful whether any appreciable difference exists, although it is quite conceivable that the different function of one side compared with the other, for instance the use of the right upper limb in preference to the left in right-handed individuals, might lead to some variation of the times of appearance of ossific centers. It has been noted repeatedly that an ossific center is present on one side although absent on the other in the corresponding bone of the same individual. Of 25 such examples, the centers were noted 16 times to be present on the right side but not on the left, while in the other 9 they were present on the left but not on the right.

Menees and Holly traced 11 infants with asymmetrical development of epiphyseal centers (7 times present on the right side and 4 times on the left, in each case being absent on the opposite side) and found that the hand preferred for use coincided in 9 instances with the side on which the epiphysis or center for the carpal bone was present and differed in the other 2 instances. In one case, the center was present for both

the head of the humerus and cuboid on the right side but not on the left. It would certainly be impossible to account for these occurrences on the score of endocrine or of any other general disturbance.

In the most recent work by Francis and Werle, the left sides only were examined, it being assumed for practical purposes that both sides are alike, but that this is not invariably the case is shown by numerous examples.

ORDER OF APPEARANCE

Köhler has stated that the order of appearance of epiphyses is not necessarily the same upon both sides, even in the same individual, as may be noted in the example of the carpal bones of a boy aged 6 years and 11 months quoted later on (Fig. 3) in the series where the multangulum majus is well marked on the left, but completely absent on the right and, although the lunate has just appeared upon the right, there is no trace of this carpal on the left. This does not accord with Pryor's observations, which are accepted by Francis and Werle: "Regardless of the variations (normal) the ossification is bilaterally symmetrical." It would be difficult to account for the asymmetry on account of illness (unless localized to one side), endocrine dysfunction, diet, etc. Nor are they necessarily the same in twins, as shown by Borovansky and Hnévkovský, who figure the hands of twin boys aged 6, where in one boy, the navicular was present on one side, but not on the other, and was absent on both sides in the brother. In the first boy the multangulum minus was present on both sides, but absent on both sides in the brother.

Fig. 4. Male, aged sixteen. Note date December 16, 1929. Well marked interval separating olecranon epiphysis from diaphysis. Compare with Figure 5. To illustrate time of closing.

Fig. 5. Same individual as that in Figure 4. Note date May 29, 1930. Suture line between epiphysis and diaphysis now completely disappeared.

TIME OF FUSION

With regard to the time of fusion, that this process usually occupies only a few months seems to be indicated by an observation of the epiphyseal plate between the tip of the olecranon process and the

diaphysis of the ulna in a subject aged 15 which showed as a considerable gap on the roentgenogram on December 16, 1929 (Fig. 4), but on May 29, 1930 (Fig. 5) not the slightest trace of the epiphyseal line could be detected, despite the particularly favorable view one obtains of this center in the lateral view. I believe that Galstaun's classification into "commencing union," "earlier stage of same process," "nearly complete union" and "union just complete," is superfluous and unnecessarily complicates the observations. I have merely noted non-fusion or fusion, the latter referring to entire disappearance of the epiphyseal plate, which is in most cases not difficult to determine. A linear shadow which may sometimes persist even for years at the junction of epiphysis and diaphysis is interpreted as fusion. When comparing Galstaun's records, his classification "union just complete" is included with fusion, and the other descriptions as non-fusion. Stevenson, as well as Sidhom and Derry, has likewise described several stages of fusion.

In all ages in this series, the ages quoted are the ages at the last birthday.

PERSISTENT EPIPHYSIS

It is rare indeed that any of the important epiphyses, such as the main proximal and distal epiphyses of the long bones, persist throughout life, yet some of the minor, and also the rarer ones do occasionally persist, more particularly those at the tips of the various processes of the vertebrae. The persistence of the rarer epiphyses at the base of the fifth metatarsal, and the posterior tubercle of the calcaneum occurs but seldom.

MATURATION STUDY

Todd has brought out an Atlas of Skeletal Maturation limited to the hand, showing the appearance at varying ages from birth until maturity, and divided into different stages of maturation. Since Todd's death, similar atlases are being prepared for other regions.

TABLE I

Age Groups	Females			Males		
	(a)	(b)	(c)	(a)	(b)	(c)
Under 10	85	11	12.9	149	9	6.0
10 to 19	137	15	10.9	195	13	6.7
20 to 29	106	12	11.3	111	7	6.3
Total	328	38	11.6	455	29	6.4

THE HEAD

METOPIC SUTURE

An examination of posteroanterior projections of 783 skulls at all ages from birth up to 29 years was made to determine the history of fusion of the two halves of the frontal bone in the middle line at the metopic suture. Table 1 indicates the frequency of existence of non-fusion in each sex in each age group respectively.

(a), (b) and (c) refer to numbers of subjects examined, numbers of unfused sutures and percentages of non-fusion in each sex in each age group respectively.

From Table 1, it is apparent first that the unfused suture is found nearly twice as frequently in the female as in the male, and secondly that there is no considerable difference in the frequency in any of the age groups, the small preponderance of sutures in the females under the age of 10 possibly being due to the relatively small number of subjects examined in this group. It therefore appears evident that when fusion of the sutures takes place, in the vast majority of instances it occurs within a few

years of birth and only rarely later on in life, and that if fusion does not take place early it probably persists in most instances until late in life (Fig. 6).

SEMICIRCULAR CANALS

Hill has shown in a study of fetuses that the semicircular canals were not ossified in 3 fetuses of an estimated age of 8 weeks, that of 19 estimated aged 12 weeks, 12 showed this feature, while of 32 estimated 16 weeks old, all showed these canals. In older fetuses, these canals become increasingly obscured with advancing mineralization of the squamous and petrous temporal.

HYOID BONE

Hill has noted the presence of this bone in the fetus at 20 weeks' gestation in both sexes. He has observed them at this period in the white race as well as in negroes. It is not invariably present at full term in either sex, or in either the white or negro race.

VERTEBRAL COLUMN

It appears that no systematic roentgenological study of the ages of appearance for the centers of the vertebral epiphyses has ever been made—at least such has not been discovered in the literature. Only a few very brief and incomplete notes are included here. Somebody, it is hoped, may be induced to make a much more complete investigation.

In a fetus measuring 32.5 mm., no center had yet appeared for any of the vertebrae. (Although the estimated age according to Keibel and Mall is 9 weeks, it was aborted 49 hours after a single coitus.)

Fig. 6. Age twenty-seven. Incomplete closure of metopic suture.

Fig. 7. Male, 70 mm. (12 weeks). Primary centers present for most long bones, scapula and ilium. Neural arches appear before vertebral bodies above, and after, below.

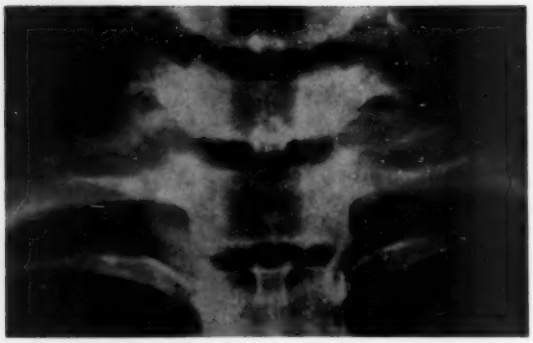

FIG. 8. Female, aged thirteen. Epiphyses for tips of transverse processes of first two thoracic vertebrae present on each side. (Courtesy of Dr. J. D. Camp, Rochester, Minnesota.)

CERVICAL VERTEBRAE

Although the seven primary centers for the neural arches were present in every fetus of 62 mm. in length (11½ weeks) or larger, no center had as yet appeared in a male fetus of 70 mm. (12 weeks) for any of the vertebral bodies, although that for the last cervical vertebra was already visible in a female fetus of 62 mm. (11½ weeks). Five pairs of centers of the lower five cervical vertebrae were noted in a male fetus of 109 mm. (15 weeks) and in a female of 125 mm. (16 weeks), while in another female of 175 mm. (20½ weeks) six were present. All larger specimens as well as a number of smaller ones, including a male of 147 mm. (18 weeks) and both male and female of 165 mm. (20 weeks) showed centers for all the cervical vertebral bodies. In the cervical region, the neural arches appear before the vertebral bodies, thus differing from the caudal extremity of the spine (see Fig. 7).

FUSION OF POSTERIOR ARCH OF ATLAS

In 2 girls aged 9 years and 1 month and 12 years and 1 month respectively, the arch of the atlas had not fused in the middle line posteriorly.

THORACIC AND LUMBAR VERTEBRAE

Primary centers for both bodies and neural arches were present for all thoracic and lumbar vertebrae in every fetus of 62 mm. (11½ weeks) or older.

UPPER AND LOWER EPIPHYSEAL PLATES FOR VERTEBRAL BODIES

These are best seen in the lateral view and are then most conspicuous forming a flattened triangular contour in front. In a girl aged 12 years and 5 months, such plates were noted in the thoracic region. In another girl aged 13 years and 5 months, they were noted upon the upper surfaces of the last thoracic and all five lumbar vertebrae and on the lower surfaces of the last two thoracic and first lumbar but not on the lower four lumbar vertebrae.

CENTERS FOR TRANSVERSE PROCESSES

In a boy aged 17 years and 7 months, secondary centers for the transverse processes of the last cervical were seen on both sides as well as those for the second thoracic on the right and the third thoracic on the left. They were not evident on the left of the second or the right of the third thoracic vertebra.

In a girl aged 13 years (see Fig. 8), centers for the extremities of the transverse processes of the first two thoracic vertebrae were noted. In a boy aged 14 years and 8 months, centers for the tips of the transverse processes of the first thoracic vertebra were likewise seen.

In a girl aged 13 years and 5 months, such epiphyses were seen on both sides of the first and third, and the right side of the fourth and left side of the fifth lumbar vertebra. They were not seen on either side of the second, the left side of the fourth nor the right side of the fifth lumbar vertebra.

Those of the first lumbar vertebra frequently persist throughout life as a separate ossicle, the homologue of the rib in the lumbar region.

PERSISTENT EPIPHYSES FOR THE VERTEBRAL PROCESSES

The persistence of epiphyses at the extremities of the transverse and spinous processes, and also over the upper and lower articular processes of the various vertebrae is important mainly because of their confusion with fractures, but so far

no exact study can be gleaned as to the period of their appearance.

CENTER FOR SACRALIZED LUMBAR VERTEBRA

This common anomaly is evidently produced by a separate center of ossification, for which the term lateral mass of lumbar vertebra is suggested to indicate that it is in series with the lateral mass of the sacrum below.

In a girl aged 3 years and 7 months (see Fig. 9), such an epiphysis is noted for the fifth lumbar vertebra on the left side, although none such is present on the right. It has not yet fused with the lumbar vertebra with which it is in contact, and has not yet reached the sacrum.

CENTERS FOR BODIES OF SACRAL VERTEBRAE

Unlike the cervical vertebrae, the primary centers for the bodies appear before those for the neural arches, those for the bodies of the first two segments being already present in the female fetus of 62 mm. ($11\frac{1}{2}$ weeks) and the male of 70 mm. (12 weeks), and although all five bodies were visible in the male of 90 mm. ($13\frac{1}{2}$ weeks),

Fig. 9. Female, aged three years seven months; center present for process of sacralized lumbar vertebra on the left but not on the right. (Courtesy of *Medical Journal of Australia*.)

Fig. 10. Male, aged seventeen years eight months. Note epiphyses on lateral aspects of lateral mass. (Courtesy of Dr. E. N. Cleaves, Boston, Massachusetts.)

there were but three only in the male of 109 mm. (15 weeks), four only in the male of 147 mm. (18 weeks), and the female of 233 mm. (26 weeks). The smallest female showing four centers measured 150 mm. ($18\frac{1}{2}$ weeks), and the smallest showing all five centers (see Fig. 11) was 165 mm. (20 weeks) in length. There is evidently a wide variation in the time of appearance of these centers.

CENTERS FOR NEURAL ARCHES OF SACRAL VERTEBRAE

The earliest appearance for the neural arches of the first sacral segment was seen in the female in a fetus of 62 mm. ($11\frac{1}{2}$ weeks) and in the male in a fetus of 109 mm. (15 weeks) and for the second segment in a male of 147 mm. (18 weeks). The earliest for the third and fourth segments were noted for a female 150 mm. ($18\frac{1}{2}$ weeks). and for a male 165 mm. (20 weeks) in length. The smallest male showing all five pairs of arches was 171 mm. ($20\frac{1}{2}$ weeks) in length and the smallest female 205 mm. (23 weeks). On the other hand, in considerably larger fetuses, up to 316 mm. (36 weeks) in a male and 298 mm. (34 weeks) in a female, the arches for the fifth segment had not yet appeared.

CENTERS FOR LATERAL MASSES OF SACRUM

The lateral masses of the sacrum are developed from three primary centers on each

FIG. 11. Male, 275 mm. (31 weeks). Arrows point to cervical ribs on both sides and to manubrium sterni. Three other sternebrae present. Center and arches of five sacral segments as well as two centers for lateral masses on each side, also ilium, ischium and pubis present.

side. The centers for the first pair were noted earliest in a male fetus 180 mm. long (21 weeks) and in a female 220 mm. (25 weeks). The second pair (see Fig. 11) were seen in a female 220 mm. long (25 weeks), as well as in all larger specimens. The third pair were noted in the female of 220 mm. (25 weeks) on one side only and in a male of 312 mm. in length (33 weeks). They were not present, however, in a female of 315 mm. (36 weeks) nor in a male of 334 mm. (38 weeks).

In a girl aged 3 years and 7 months, the lateral mass had not yet fused upon either side.

EPIPHYSES OVER LATERAL ASPECTS OF SACRUM

Cleaves has studied in 16 American boys only by means of stereoscopic roentgenograms (Fig. 10) the epiphyseal plates situated on the lateral aspects of the sacrum, that is, over the parts formed by fusion of the three centers for the lateral masses and finds the incidence of their presence as follows: (a) representing the number of boys examined, (b) the number showing the presence of these epiphyses and (c) the number in whom such have been found to be fused (Table II).

Some of the boys have been submitted to repeated examinations up to four times per year. The youngest boy showing such center was aged less than 13, the same boy was also the youngest in whom they had fused at the age of 15. The oldest boy in whom the epiphysis had not yet appeared was aged 18 years and 2 months. In the former, an interval of but 2 years and 1 month intervened between the observed time of non-appearance of this epiphysis and the date of its fusion. The longest interval noted between the observed dates of unfused epiphysis is 2 years and 4 months so that the time of appearance is apparently a brief one, and it is present in the majority of boys at the age of 16, which is also the age of maximum incidence. Fusion apparently takes place in the majority of boys at the age of 18.

TABLE II

Ages	(a)	(b)	(c)
12	8	1	0
13	9	1	0
14	10	4	0
15	11	5	1
16	9	7	0
17	5	4	1
18	4	1	3
19	2	0	2

I have seen this epiphysis on each side in 2 girls aged 13 years and 8 months and 2 boys aged 14 years and 8 months, and 18 years and 2 months respectively.

COCCYX

The only center for the coccyx seen before birth was that for the body of the first segment. It was noted earliest in a female

fetus of 262 mm. (30 weeks) and in a male of 296 mm. (33 weeks), but not present in a female 324 mm. (37 weeks) nor in a male 334 mm. in length (38 weeks). After birth the rectal contents often obscure to a large extent a clear view of the coccyx, so that it is relatively infrequent to be certain which centers for this bone have appeared.

Although present in a female aged 8 months and in 3 males during the second and third years, in a girl aged 3 years and 7 months the first segment had not yet appeared. This latter is the same subject in whom a center for a sacralized lumbar vertebra was present, indicating an apparent cephalad shifting of the sacrococcygeal portion of the vertebral column.

In a boy aged 7 years and 4 months although the coccygeal cornu was already formed on the right side, upon the left it was represented by two distinct and detached ossific centers.

In a girl aged 5 years and 4 months and a boy aged 10 years and 7 months, the second segment had not yet appeared, while in a girl aged 10 years and 0 months and a boy aged 12 years and 0 months, centers were present for all four segments.

In a woman aged 23 years and 6 months, there was not yet any appearance of the center for the third segment. Of 16 females between the ages of 11 to 23 inclusive, this center was found in 14, although present in all of 19 males of the same age period.

The fourth coccygeal segment was not present in a woman aged 25 years and 7 months, nor in a man aged 27 years. Possibly its absence persists throughout adult life in some individuals. Of 22 females and 18 males between the ages of 11 and 25 (inclusive), this segment was missing in 9 females and 4 males.

CENTERS FOR STERNEBRAE

The several centers for the sternum are by no means as regular in their arrangement as are those of the vertebrae or of the ribs (see Fig. 11). The first three centers were noted earliest in a male fetus 180 mm. (21 weeks) in length; the earliest showing four centers was a male of 218 mm. (25 weeks). Five centers were present in a male fetus 283 mm. long (32 weeks), and the first to show six centers was a female 295 mm. in length (33 weeks).

RIBS

A fetus of 32.5 mm. expelled 49 days after a single coitus showed 10 pairs of ribs, although another of 30 mm. did not show any. All fetuses 62 mm. (11½ weeks) and longer possessed at least eleven pairs of ribs. However, although a female of 62 mm. as well as 29 other fetuses of 90 mm. (13½ weeks) or longer had all twelve pairs, there were 5, including a female 298 mm. (34 weeks) long and a male of 315 mm. (36 weeks), in which only eleven pairs were present.

CERVICAL RIBS

Cervical ribs were noted to be present in quite small fetuses (see Fig. 11), namely in a female of 165 mm. (20 weeks) and a male of 134 mm. (17 weeks).

Sir William Turner quotes Rosenmuller as having described a six months' fetus with a cervical rib.

UPPER LIMB

Primary centers for the clavicles, scapulae, humeri, radii, and ulnae were present in all fetuses of 32.5 mm. (49 days) and over (see Fig. 6). Those for the metacarpals and proximal and distal rows of phalanges were also present in all fetuses of 62 mm. (11½ weeks) and over (see Fig. 6). Those for the metacarpals and distal rows of phalanges were also present in all fetuses of 62 mm. (11½ weeks) and over.

PRIMARY CENTER FOR CLAVICLE

The clavicle was noted on each side as the sole center in a male fetus of 30 mm. in length (9 weeks) (see Fig. 12). Mall records its presence in a fetus of 15 mm. (6½ weeks) but it is possible that those shown by his peculiar clearing method may not be demonstrable by roentgen examination owing to insufficient calcification. The condition of cranioclеidodysostosis evidently has its origin prior to the ninth week of fetal life.

EPIPHYSIS FOR CLAVICLE

The medial extremity of the clavicle was noted in 862 instances under the age of 30. The youngest female in whom an epiphysis was noted was aged 11 years and 7 months, and the youngest male 11 years and 8 months in whom it was present on the left side, the oldest being 25 years and 11 months in a female in whom it was present on the left but absent on the right and in a male, aged 25 years, on both sides. Stevenson states that it may be delayed until 28

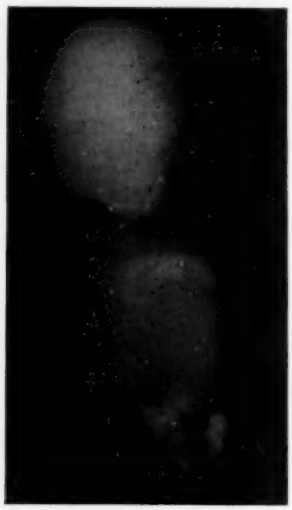

FIG. 12. Male, 30 mm. (nearly 9 weeks). Clavicles only bones ossified.

years but of the 24 instances in individuals aged 27 to 29 no epiphyses were seen. At no age do more than 65 per cent of clavicles appear to be possessed with epiphyses, suggesting the possibility that the epiphyseal center for this bone is not a constant feature, but it must be remembered that such centers are frequently difficult to demonstrate, partly owing to the irregularity of the sternal extremity of the clavicle, and partly to a mixed background of intrathoracic structures, vertebrae and posterior parts of the ribs, while confusion with costotransverse and and costocentral articulations is likely to be encountered.

Table III illustrates the frequency of occurrence of such epiphyses. Columns (a) represent the number of clavicles examined, and (b) the number of epiphyses found in each sex in each age group respectively.

In Table III half of the females aged 17 and the majority of the males aged 19 and 21 years possess epiphyses for the sternal

TABLE III

Age	Females		Males	
	(a)	(b)	(a)	(b)
11	15	2	5	2
12	15	0	11	1
13	6	2	15	0
14	8	2	11	2
15	17	4	11	1
16	19	4	16	1
17	20	10	20	7
18	11	9	20	3
19	36	14	14	8
20	41	16	23	7
21	26	11	26	17
22	20	5	19	7
23	23	4	20	5
24	26	4	30	2
25	26	2	27	2
26	12	1	12	0

end of the clavicle, but the majority of both sexes at all other ages show absence of such epiphyses.

PRIMARY CENTER FOR SCAPULA

This was noted in all fetuses of 32.5 mm. (49 days after single coitus) and over.

EPIPHYSIS FOR INFERIOR ANGLE OF SCAPULA

The epiphysis for the inferior angle of the scapula was clearly demonstrated in 3 subjects only, namely, 2 females aged 17 and 18 years and 11 months respectively in both of whom it was present in both sides (see Fig. 13) and in a male aged 16 years and 10 months. This center is evidently rarely seen, probably because this angle of the scapula is usually obscured by the lateral aspect of the bony cage of the chest, and also because this part of the bone is generally displayed lying in a sagittal direction.

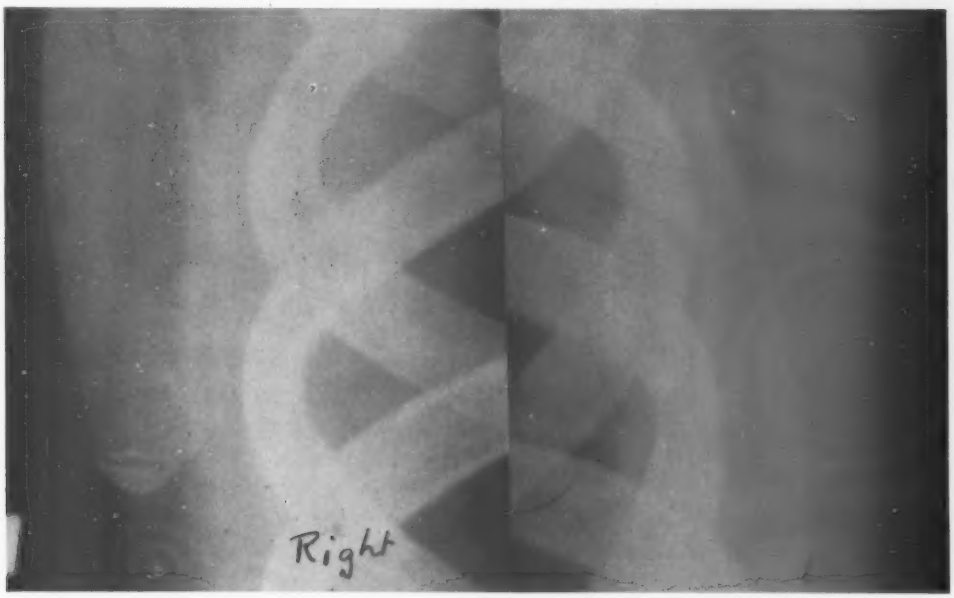

Fig. 13. Female, aged seventeen. Centers present for inferior angle of scapula on each side.

MAIN EPIPHYSIS FOR CORACOID PROCESS

Of 237 female and 263 male infants within 48 hours after birth, Menees and Holly found the center for the main part of the coracoid process in 32 instances (13.5 per cent) in the female and 28 (10.6 per cent) in the male.

Hill noted this epiphysis in only 1 each of 39 female and 69 male fetuses of an estimated age of 28 weeks. At full term, it was recorded in 7 of 45 females and 8 of 73 males.

In my series, the cartilaginous junction of the coracoid process with the body of the scapula was especially noted on both sides in a female infant aged 8 months and in 4 girls between the ages of 4 years and 2 months and 7 years and 6 months inclusive, when the arm was elevated above the horizontal (see Fig. 14). It was likewise seen in boys aged 5 years and 11 months and 10 years and 3 months respectively. Regular observations of this process are rendered difficult by the overshadowing of the coracoid by the spine of the scapula as well as by the clavicle and head of the

Fig. 14. Female, aged five. Showing center for main part of coracoid process.

FIG. 15. Male, aged fourteen years seven months. Epiphyses present for head and greater tubercle of humerus, acromion process, angle of coracoid and tip of coracoid.

humerus in the ordinary position of the shoulder with the arm adducted to the side.

EPIPHYSIS AT ANGLE OF CORACOID PROCESS

This epiphysis (see Fig. 15) is usually present at the junction of the ascending and horizontal rami on the medial aspect, where it forms a thin scale of bone. Table IV illustrates its incidence, columns (a) referring to the number of such processes examined and columns (b) the number of epiphyses found in each sex respectively.

The youngest instance where this was noted was a girl aged 10 years and 2 months, in whom it was present on the right side but absent on the left. This was the only epiphysis out of 71 instances in both sexes aged 10 to 12 inclusive, but examples were noted in a girl, aged 13 years and 7 months, on both sides and in a boy at the age of 14 years and 7 months. Of 295 instances (including 143 females and 152 males) aged 13 to 19 there were only 8 (5.6 per cent) in the female although there were 32 (21.0 per cent) in the male, suggesting a probability of greater frequency in the latter. In any case, the rarity of these centers makes it reasonably certain that the epiphysis is not a constant feature in the human subject. It would appear that in the female the appearance as well as the fusion with the ramus is earlier than in the male; thus of 83 females aged 17, 18, and 19, no epiphyses were seen, although 18 such were found present in the same number of males of the same age. The epiphysis was most frequently found in females at the age of 13 and in males at the age of 16. The oldest female with unfused epiphysis was aged 16, in whom it was present on both sides and the oldest male 19.

EPIPHYSIS AT TIP OF CORACOID

In boys aged 14 years and 7 months (see Fig. 15) and 15 years respectively, not only were the usual centers present for the angle of the coracoid and the acromial epiphysis, but there were additional centers for the tip of the coracoid. In another boy aged 16 a similar center for the tip of the coracoid was present as well as additional centers for the acromion process although that for the angle of the coracoid was absent.

TABLE IV

Age	Females		Males	
	(a)	(b)	(a)	(b)
13	8	4	19	0
14	9	1	16	2
15	17	1	16	5
16	26	2	18	7
17	33	0	25	6
18	11	0	32	11
19	39	0	26	1

EPIPHYSIS AT ACROMIAL MARGIN

The center for the posterolateral margin of the acromion process sometimes consists of two or more fragments and is often seen in the same roentgenogram showing the presence of the epiphysis for the angle of the coracoid (see Fig. 15). For clear demonstration, the roentgenogram should not be overexposed. Many views of the shoulder joint, even when clearly defining the various details of the joint itself, had to be excluded from consideration because of obliteration of detail of the acromion process with the result that a much smaller series was available for examination than in the case for instance of the coracoid process.

Table V illustrates its incidence, columns (a) representing the number of processes

examined, and columns (b) the number of epiphyses seen in each sex at each age group respectively.

The earliest appearances were in a girl aged 12 years and 0 months, in whom it was present on both sides and in a boy at the age of 14 years and 11 months. It was present in the majority of females at the age of 14 and of males at the age of 15 years, and was fused in all instances in females at the age of 17 and in the majority of males at the same age. While the oldest female with an epiphysis was aged 16 years and 1 month, the oldest male was aged 19 years and 2 months.

Table V

Ages	Females		Males	
	(a)	(b)	(a)	(b)
12	3	3	3	0
13	6	2	8	0
14	4	4	10	4
15	13	5	12	6
16	7	4	12	10
17	16	0	9	4
18	8	0	14	6
19	14	0	19	2

Again, it is by no means certain that a center always appears at the distal end of the acromion, for in 158 instances aged 12 to 19 (including 71 females and 87 males) there were but 50 (31.6 per cent) epiphyses (inclusive of 18 females and 32 males) noted.

PRIMARY CENTER FOR HUMERUS

This was found present in all fetuses in this series of 32 mm. (49 days after single coitus) or over (see Fig. 7).

EPIPHYSEAL CENTER FOR HEAD OF HUMERUS

Centers for the head of the humerus were found very much earlier than is indicated in the literature. Spencer, for instance, found it in the days long before roentgen rays were discovered, 9 times in 40 fetuses weighing 7 pounds or more. He could not find centers in 2 others weighing 10 pounds 12 ounces and 11 pounds 4½ ounces respectively.

Fig. 16. Female, 294 mm. (33 weeks). Note center for head of humerus.

However, in the present series, centers were quite clearly distinguished in a female fetus of 294 mm. (33 weeks) (see Fig. 16) and in a male of 295 mm. (33 weeks). As out of 10 fetuses of 294 mm. (33 weeks) and larger, 6 showed the presence of this epiphysis, it seems probable that the frequency of appearance of this center before birth has been considerably underestimated and this center ranks next in order of appearance to that of the distal femoral epiphysis and proximal tibial epiphysis.

Hill recorded this center present in 1 each of 26 female and 36 male fetuses of estimated age of 32 weeks and in 12 of 35 female and 11 of 49 male full term fetuses.

Menees and Holly found that of 237 females and 263 males within 2 days after birth, the center was present in 112 females (47.2 per cent) and 122 males (46.4 per cent).

Of 40 instances in babies during their first year, the oldest without epiphyseal center was a girl aged 1 month and a boy aged 6 months. The earliest centers noted were 2 months in each sex. All older children showed the presence of this epiphysis.

FIG. 17. Male, aged one year three months. Head of humerus is distinct from that for greater tubercle.

EPIPHYSIS FOR GREATER TUBERCLE OF THE HUMERUS

Many roentgenologists, notably Cohn, have doubted the existence of a separate center of ossification for the greater tubercle, and are of the opinion that this process is developed from extension of the center for the head over the lateral aspect of the diaphysis, but in numerous instances in young children (see Fig. 17), each center has been noted side by side, one for the head lying on the inclined plane on the medial aspect and the other on another inclined plane on the lateral side of the upper aspect of the diaphysis. Unfortunately in many instances, the head of the humerus is obscured by the overhanging acromion process or even by the coracoid, so that it is frequently difficult to define the center for the greater tubercle and to separate it from the head proper. Borovansky and Hnévkovský give very good diagrams illustrating the appearance of the head and greater tubercle in boys of Prague at various ages from 4 years and 1 month up to 14 years and 7 months.

The incidence of appearance of this epiphysis is represented by Table VI. Columns (a) represent the number of humeri examined and columns (b) the number of epiphyses noted at each age in each sex respectively.

TABLE VI

Age	Females		Males	
	(a)	(b)	(a)	(b)
Under 1	8	4	15	8
1	9	7	16	3
2	7	7	11	7
3	10	7	8	6
4	7	3	7	6
5	9	4	12	3
6	13	3	4	2

During the first year after birth, the earliest epiphysis for the greater tubercle was noted at 8 months in a girl and 6 months in a boy. Its absence was also noted at 11 months in a female while it was present in all 7 instances in females aged 2. In a boy aged 9 months, it was present on the left but not on the right side. Half of the epiphyses were noted present in girls during the first year and in the majority of boys during the third year. Paterson reports the appearance of this center at the end of the second or beginning of the third year, practically a year later than the above series of observations seem to show. Most other anatomists give 2 to 3 years.

FUSION OF EPIPHYSEAL CENTERS FOR GREATER TUBERCLE AND HEAD OF HUMERUS

After the first 2 years or earlier, the center for the greater tubercle overlaps that for the head of the bone, the two later fusing to form a conjoint epiphysis (see Fig. 18). The earliest instance of such fusion is seen in a girl aged 3 years and 7 months (both sides), but that for boys is not apparent from the above table. The

latest to fuse were in a girl aged 6 and a boy aged 6 years and 6 months, the majority fusing at the age of 4 in girls and 5 in boys. In all children over 6, including 43 aged 7 to 9, these two epiphyses had fused, but Davies and Parsons report an instance of non-fusion at the age of 12. In a boy aged 9 (not included in this series), the subject of craniocleidodysostosis, these epiphyses had not yet fused.

EPIPHYSIS FOR LESSER TUBERCLE OF HUMERUS

Like other roentgenologists, I have failed to find a single example showing the presence of this center, and doubts have been raised concerning its existence. However, the position of the lesser tubercle in front of the bone would certainly make such a center, even if it were present, much more difficult to demonstrate, especially as it is usually impossible to secure a good lateral view of this portion of the limb. Practically all anatomists describe the presence of this epiphysis.

FUSION OF UPPER CONJOINT EPIPHYSIS WITH DIAPHYSIS OF HUMERUS

The incidence of fusion of the upper conjoint epiphysis of the humerus is represented by Table VII. Columns (a) show the

TABLE VII

Age	Females		Males	
	(a)	(b)	(a)	(b)
15	11	1	17	0
16	10	3	17	1
17	25	15	21	3
18	9	8	6	4
19	27	22	23	17
20	24	22	14	14

number of humeri examined and columns (b) the number of instances in which such centers have been found fused at each age in each sex respectively.

From the figures in Table VII, it seems that the age of fusion of the conjoint epiphysis for the head and the greater

FIG. 18. Age four years. Commencing union of epiphyses for head and greater tubercle of humerus, forming socket into which fits as a cap conical upper extremity of diaphysis.

tubercle with the diaphysis is fairly constant, much more so than is the case with the great majority of other epiphyses. The earliest fusion was at the age of 15 years and 8 months in a girl and 16 in a boy, the latest 20 years and 5 months in a female (both sides), and 19 years and 2 months in a male. The majority were fused at the age of 17 in females and 18 in males. Union was constantly found at 21 in females and 20 in males, which fact does not at all correspond to the various ages, 20 to 25 given by numerous anatomists, and also which differs appreciably from the ages given by Paterson, namely 18 for females and 21 for females.

EPIPHYSIS FOR LATERAL EPICONDYLE

Table VIII records the incidence of the epiphysis for the lateral epicondyle, columns (a) referring to the number of elbows examined, columns (b) the number of epiphyses present at each age in each sex respectively.

The earliest centers observed for this epiphysis were in a girl aged 8 years and 6 months and in a boy aged 10 years and 7 months. At the age of 11 in females and 12 in males, this epiphysis was found present in the majority of instances, while the oldest subjects with unfused epiphyses were aged 16 in each sex (both sides in a female).

TABLE VIII

Age	Females		Males	
	(a)	(b)	(a)	(b)
8	13	2	18	0
9	6	2	17	0
10	6	2	19	3
11	7	6	11	4
12	1	1	23	15
13	8	4	16	12
14	8	1	18	14
15	8	0	12	8
16	6	2	11	1

Despite the opinions of Cohn and Paterson, this epiphysis is probably present, like those of the capitulum, trochlea and medial epicondyle in every case at some period between the ages of 7 and 17 years. In the female, it was present in 11 instances out of 16 (69 per cent) between the ages of 11 and 13, and in the male in 41 of 57 instances (72 per cent) aged 12 to 14, or 26 of 34 instances (76 per cent) aged 13 and 14. The case figured by Paterson, which is described as an extension of the capitular epiphysis and which is stated to occur in 30 per cent of cases is certainly a fusion of the capitulum with the lateral epicondyle, which always takes place before union of the conjoint epiphysis with the diaphysis.

CENTER FOR CAPITULUM

This center had not yet appeared in a female infant aged 2 months nor in males aged 1 week, 1, 2, 8 and 9 months respectively, but was noted on both sides in a girl aged 9 months and in a boy aged 11 months as well as in all older children, including 31 instances in children aged 1 year, 35 aged 2 and 27 aged 3. Davies and Parsons report its absence in one instance at 18 months (sex not stated).

TROCHLEAR EPIPHYSIS

Table IX represents the incidence of the epiphysis for the trochlear surface of the humerus, columns (a) referring to the number of elbows examined, and columns (b) the number of epiphyses found at each age period and in each sex respectively.

The earliest centers for the trochlea were noted at the age of 7 years in a girl and 8 years and 9 months (both sides) in a boy, while the majority of girls aged 9 and half of the boys aged 10 showed the presence of this center. The epiphyses were still evident in a girl aged 16 as well as in a boy of the same age.

UNION OF EPIPHYSES OF LATERAL EPICONDYLE, CAPITULUM AND TROCHLEA

It is usual to describe the union of the epiphyses of the lateral epicondyle and trochlea on each side of the capitulum (Fig. 19) to form a new conjoint epiphysis which fuses at a later date with the diaphysis. From a roentgenological study of this series, this method of development appears to be correct, and there is no valid reason for the supposition, as suggested by Paterson, that in some 30 per cent of cases the lateral epicondyle is formed by extension from the capitulum. If this were the case, one would expect to find intermediate stages of this extension, such as may be observed in the spinous process developed from the primary center for the scapula, or the main part of the olecranon process from the shaft of the ulna, but such intermediate stages are not seen. On the contrary, the

TABLE IX

Age	Females		Males	
	(a)	(b)	(a)	(b)
7	8	1	15	0
8	14	4	20	4
9	6	5	17	5
10	7	5	18	9
11	7	6	12	8
12	2	2	23	21
13	8	4	17	14
14	8	1	21	18
15	8	0	14	11
16	4	2	10	1

adjacent margins of the epiphyses for the lateral epicondyle and capitulum prior to fusion are always smooth and well defined.

In Table x, columns (a) show the number

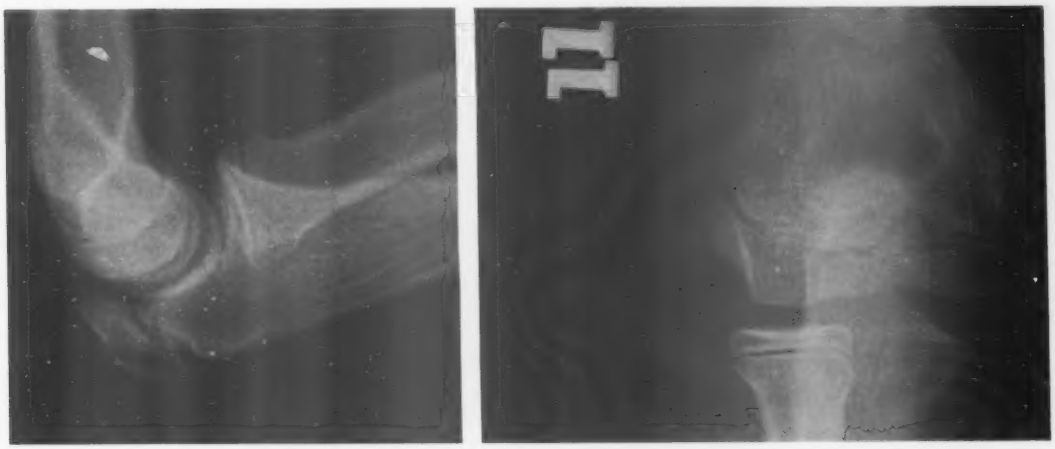

Fig. 19. Male, aged fifteen. Epiphysis of lateral epicondyle, capitulum and trochlea unite to each other, before joining diaphysis. Epiphysis for medial epicondyle distinct.

of instances in which these three epiphyses were present, and columns (b) the number of those fused to each other at each age group in each sex respectively.

The union of the lateral epicondyle and trochlea on each side of the capitulum is almost simultaneous, although the former is sometimes slightly later than the latter. The lateral edge of the trochlea is generally narrow and often ill defined, in marked contrast to the smooth surfaces of the capitulum and lateral epicondyle. In fact, the latter is somewhat discoidal in shape and sometimes appears to belong to the capitulum rather than to the shaft of the bone. In a boy aged 14 years and 7 months, the capitulum on each side had fused with the lateral epicondyle, but the adjacent very narrow edges of the trochlea and capitulum were still ununited.

Table X

Age	Females		Males	
	(a)	(b)	(a)	(b)
8	2	0	0	0
9	2	0	0	0
10	1	1	2	0
11	5	1	3	0
12	1	0	15	2
13	4	1	12	4
14	1	0	13	9
15	0	0	9	1
16	2	0	1	1

In a girl aged 10, the three epiphyses were fused with each other, but the earliest instance in a boy was at the age of 12, in whom they were all united on both sides. Union had taken place in the majority of the boys at the age of 14, but had not occurred in a girl aged 16 nor in a boy aged 15, in each case on neither side.

Table XI

Age	Females (Author)		Males (Author)		Males (Sidhom and Derry)	
	(a)	(b)	(a)	(b)	(a)	(b)
13	8	4	19	0		
14	8	5	22	2	91	32
15	8	8	15	4	43	33
16	6	5	10	9	95	88

FUSION OF CONJOINT DISTAL EPIPHYSIS WITH DIAPHYSIS OF HUMERUS

Table XI indicates the incidence of union of the fused distal epiphyses with the diaphysis of the humerus, columns (a) representing the number of such epiphyses examined and columns (b) the number fused at each age, in each sex, in the present series

as well as in a similar series of boys investigated by Sidhom and Derry in Egypt.

The earliest age of which union occurred was 13 years and 4 months in a girl and 14 years and 7 months in a boy. Fusion was present at the age of 13 in half of the girls and 16 in the majority of boys, but instances of non-fusion were noted at the age of 16 in both sexes (on both sides in a female). Sidhom and Derry found the majority among a larger series of Egyptian boys fused at the age of 15, that is a year earlier than in the Australian series, for while in 33 of 43 boys in Egypt, fusion had taken place, in Australia only 4 of 15 instances at the same age showed union.

TABLE XII

Age	Females				Males			
	Australian		Hindu		Australian		Egyptian	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
2	13	1			18	0		
3	6	2			16	0		
4	5	2			19	0		
5	20	17			15	7		
6	8	7			14	5		
7	9	9			17	4		
10	7	4			19	19		
11	4	3			13	13		
12	1	1			21	19		
13	8	5	7	0	16	15		
14	8	3	24	6	19	18	101	95
15	8	0	16	1	16	16	39	29
16	6	3	12	2	10	5	98	41
17	5	0	16	0	18	7	95	15
18	5	0	9	0	10	0	68	6
19	6	0	3	0	11	0	24	1

EPIPHYSIS FOR MEDIAL EPICONDYLE

The medial epicondyle (Fig. 20), unlike the lateral, is altogether separated from the other centers at the lower end of the humerus and fuses directly and independently with the diaphysis.

Table XII shows the incidence of this epiphysis, columns (a) being the number of elbows examined and columns (b) the number of instances in which the epiphyses were present in Australian girls of my series and Hindu girls of Galstaun's series and in Australian boys of my series and Egyptian boys of the series of Sidhom and Derry respectively.

The earliest age at which this epiphysis has been noted is 2 years and 2 months in a female and 5 years and 5 months in a male. This center was found in the great majority of girls at the age of 5 and of boys at the age of 7. Its absence was noted in a girl aged 6 and in a boy aged 7 years and 3 months.

The youngest girls in whom the medial epicondyle was found fused with the diaphysis were aged 10, the youngest boys 12, in 1 case being present on the right although fused on the left side. In one-half of the girls, union had taken place at the age of 14 and in one-half of the boys at 16. The center was found still unfused in a girl aged 16 years (both sides) and in a boy aged 17 years. Paterson gives the date of union as 18 to 21 in males, but in this series, in every one of 36 instances in males at these ages it was already fused, although there were 7 in Sidhom and Derry's series,

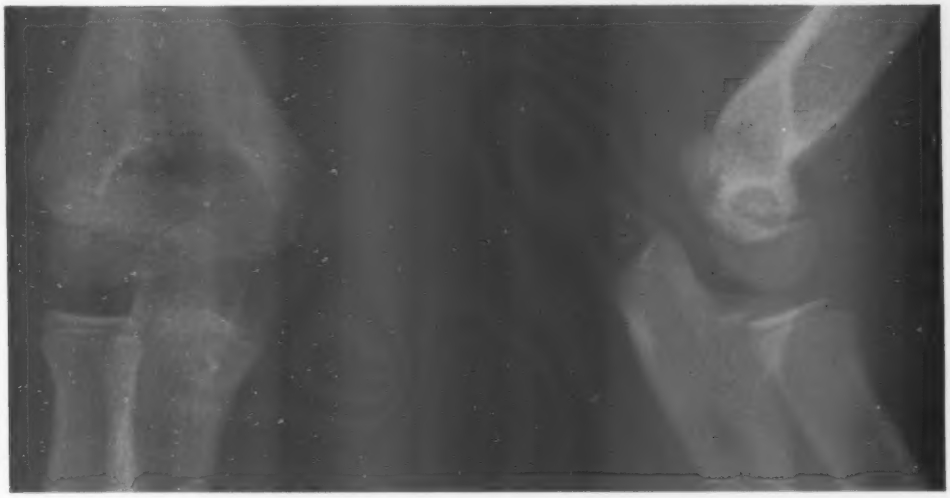

Fig. 20. Female, aged eight. Centers for medial epicondyle, capitulum and head of radius present, but not trochlea, lateral epicondyle nor tip of olecranon.

that is 6 of 68 aged 18, and 1 of 24 aged 19, the oldest aged 19 years and 3 months with unfused epiphysis.

According to the investigations of Galstaun, it would appear that fusion does not take place earlier in Hindu than in Australian girls.

PRIMARY CENTERS FOR RADIUS AND ULNA

In all fetuses measuring 32.5 mm. (49 days) or longer, the primary centers for both the radius and the ulna had already appeared (see Fig. 7).

EPIPHYSIS FOR THE TIP OF THE OLECRANON PROCESS

The main part of the olecranon process is formed by an extension upward from the diaphysis, a small wedge, including the tip alone being formed from a separate center (Fig. 20), which may or may not comprise part of the articular surface of the greater semilunar notch. Generally there is only one center, but more often there are two or more.

Table XIII represents the incidence of this epiphysis, columns (a) representing the number of elbows examined and columns (b) the number of epiphyses present in girls in my series and Galstaun's series and also in my series of boys respectively.

The youngest subjects in whom epiphyses were present were a girl aged 6 and a boy aged 7. From the above it would appear that the epiphysis is present in a majority of girls at the age of 8 and of boys at the age of 10. While fusion takes place in the majority of girls at the age of 14, union does not occur in the majority of boys until 16 years of age. Instances of non-fusion were noted in a female at the age of 16 years and in a male at 17 years and 6 months. The epiphyses had not yet appeared on either side in girls aged 10, but examples of ab-

Table XIII

Age	Females				Males	
	Australian		Hindu		Australian	
	(a)	(b)	(a)	(b)	(a)	(b)
6	9	1			21	0
7	10	1			19	1
8	14	8			22	3
9	5	5			17	3
10	7	3			19	15
11	6	6			23	9
12	2	2			27	26
13	7	5	7	7	16	15
14	8	1	24	14	22	21
15	8	0	16	2	18	16
16	5	3	12	0	5	2

TABLE XIV

Age	Females				Males			
	Australian		Hindu		Australian		Egyptian	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
3	7	2			20	1		
4	10	5			20	8		
5	22	13			16	10		
6	9	7			23	15		
7	11	11			23	19		
8	21	21			27	26		
13	10	7	7	7	18	18		
14	13	4	24	7	24	23	99	91
15	7	1	16	3	20	18	41	28
16	7	2	12	1	11	5	98	35
17	3	0	16	2	22	11	94	11
18	5	0	9	1	10	0	67	5
19	7	2			11	0		
20	4	0			15	1		

sence, whether of non-appearance or fusion, can be noted at all ages in boys. The earliest to fuse was in a girl aged 13 years and 10 months.

PROXIMAL EPIPHYSIS OF THE RADIUS

Table XIV represents the incidence of this epiphysis, columns (a) and (b) having the same significance as the corresponding columns in the table for the medial epiphysis.

The earliest epiphysis noted was in a girl aged 3 years and 4 months and in a boy also aged 3 years and 4 months. Davies and Parsons noted an instance in a girl aged 2. Half of the females aged 4 and the majority of males aged 5 showed the presence of this epiphysis. It was absent in girls aged 6 and in a boy aged 8.

The earliest age at which fusion had occurred was 13 years and 10 months in a girl and 14 in a boy. Union had occurred in the majority of females at the age of 14 and of males at 16. One woman aged 19 years and 10 months showed non-fusion on both sides, while bilateral non-fusion was also noted in a male aged 20 years and 5 months.

Sidhom and Derry found the epiphyses of the majority of Egyptian boys fused at the age of 16 as above. In one instance it was not fused at the age of 18 years and 6 months.

TUBERCLE OF RADIUS

In no instance has a separate epiphyseal center for the bicipital tubercle of the radius, as described by Frazer, been found.

DISTAL EPIPHYSIS OF RADIUS

Table XV represents the observed incidence of appearance of this epiphysis, columns (a) showing the number of wrists examined and columns (b) the number of centers present in girls of (i) my Australian, (ii) Pryor's American and (iii) Galstaun's Hindu series as well as the boys in (iv) my Australian, (v) Pryor's American and (vi) Sidhom and Derry's Egyptian series in each age group respectively.

The youngest female in whom this center was seen was aged 9 months, but it was not seen in any of 5 boys in their first year. A girl aged 1 year and 2 months showed no epiphysis on either side while a boy aged 1 year and 7 months old likewise showed no center, although present in 6 other instances in boys in their second year, the youngest being 1 year and 1 month. Cohn states that

this epiphysis is constantly present at the age of 6 months, yet in 3 males, aged 10 months, 11 months and 1 year respectively, this was not the case. The center was found in all of 22 instances of both sexes aged 2.

The youngest female in whom fusion had occurred was aged 15 years and 11 months, the youngest male 17 years and 3 months. The majority of females aged 18 and of males aged 19 showed union with the shafts. The oldest subjects in whom union was not complete were a female aged 20 years and 5 months and a male aged 23.

In the Australian series, the great majority were fused in the case of the girls at the age of 18 (in the Hindu series not until 19), and in boys at the age of 19 as in the Egyptian series of Sidhom and Derry. In 8 of the latter series, union had occurred at the age of 16. Like Galstaun, Pryor found union in American females at 19 and males at 20, that is, later than in both the Australian and the Egyptian series.

DISTAL EPIPHYSIS OF ULNA

Table XVI represents the observed incidence of appearance of this epiphysis, the grouping being the same as that of the preceding distal epiphysis of the radius.

The center for this epiphysis was first seen at the age of 5 in a girl and 5 years and 4 months in a boy. Paterson reports it present in a girl aged 4. The epiphysis was found in the majority of girls at the age of 5 and half of the boys at the age of 6. The oldest girl in whom it was found absent was aged 7, and the oldest boy 8 years and 6 months.

The youngest female in whom this center had fused was aged 15 years, the youngest male 17 years and 3 months. It will be noted that while the majority of epiphyses had fused at the age of 17 in females, it was not until the age of 19 that union was present in the majority of males. The oldest female in whom this center had not yet fused was aged 22 and the oldest male 23. Paterson's conclusion that "it joins the shaft at the same time as the radius, namely at 21 in the male and a year earlier in females," implies a considerably later date of fusion, that is at least two years later than is the case with the majority of the series of Australian, Egyptian and American subjects. It is true, however, that fusion of the lower epiphyses with the diaphyses of the radius and ulna are practically simultaneous.

The remarks made with reference to the lower end of the radius apply as well to the lower end of the ulna, thus it would appear

TABLE XV

Age	Females						Males					
	(i)		(ii)		(iii)		(iv)		(v)		(vi)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
0	3	3					5	0				
1	12	9					7	6				
14	8	8	14	14	24	22	49	49	2	2	104	104
15	7	6	6	6	16	12	48	48	3	3	41	41
16	14	10	12	12	12	8	44	44	4	4	99	91
17	12	7	17	11	16	11	41	40	14	13	90	74
18	16	3	7	4	9	5	42	35	12	12	70	36
19	6	1	10	4	3	1	32	12	8	6	23	7
20	8	1	6	0			21	6	6	1		
21	5	0	1	0			30	6	2	0		
22	7	0	2	0			22	0	5	0		
23	11	0					20	1				

TABLE XVI

Age	Females						Males					
	(i)		(ii)		(iii)		(iv)		(v)		(vi)	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
5	3	2					11	4				
6	9	6					12	6				
7	7	6					27	16				
8	14	14					16	11				
14	8	8	14	14	24	23	49	49	2	2	104	104
15	7	5	6	6	16	13	48	48	3	3	41	40
16	13	9	12	12	12	8	43	43	4	4	94	85
17	11	5	17	11	16	12	37	36	14	13	87	61
18	16	3	7	4	9	5	40	32	12	10	69	33
19	6	0	10	4	3	2	31	9	8	1	24	6
20	9	1	6	0			19	3	6	0		
21	5	0	1	0			30	4	2	0		
22	8	1	2	0			22	0	5	0		
23	11	0					18	1				

that, in Galstaun's Hindu series, with the exception of a few instances, fusion does not take place generally at an earlier age than in this Australian series of European descent. Sidhom and Derry found that the majority of Egyptian males aged 18 show fusion, that is a year earlier than in the Australian series. In one boy in their series, fusion was present at the age of 15 years and 11 months. Pryor found union in the majority of American girls at 16 and of boys at 19, in the former case earlier than in the Australian series, although the boys are later than in the Egyptian series.

EPIPHYSIS FOR STYLOID PROCESS OF ULNA

Borovansky and Hnévkovský found a separate epiphysis for this process in a boy aged 5 years and 10 months, on both sides. They report 2 instances of this epiphysis, one of which is illustrated.

In a boy aged 13 years and 10 months, a separate ossicle representing the detached styloid process of the ulna is seen. This does not appear to have been caused by injury. In view of the frequency with which the styloid process is detached by trauma, it is important to recognize that this process may exist separately and independently as a separate ossicle.

CARPAL BONES

None of the carpal bones were seen in any fetus of my series, and no record of such has been discovered in the literature. With the possible exceptions of the capitate, and less frequently of the hamate, these ossicles probably never appear before birth.

Each of these as a rule is developed from a single center. Woollard states that two centers have been found for the navicular. Pfitzner has described a double center for the triquetrum, while Quain reports two centers being sometimes found for the lunate. Adair and Scammon report double centers for the capitate. In this series, double centers for the multangulum minus were noted in a girl aged 6, on the right side, but not on the left (see Fig. 21). Borovansky and Hnévkovský found these present on both sides in a boy aged 5 years and 10 months.

The order of appearance is by no means constant, for even in the same individual it may be different on each side, Thus (see Fig. 3), in a boy aged 6 years and 11

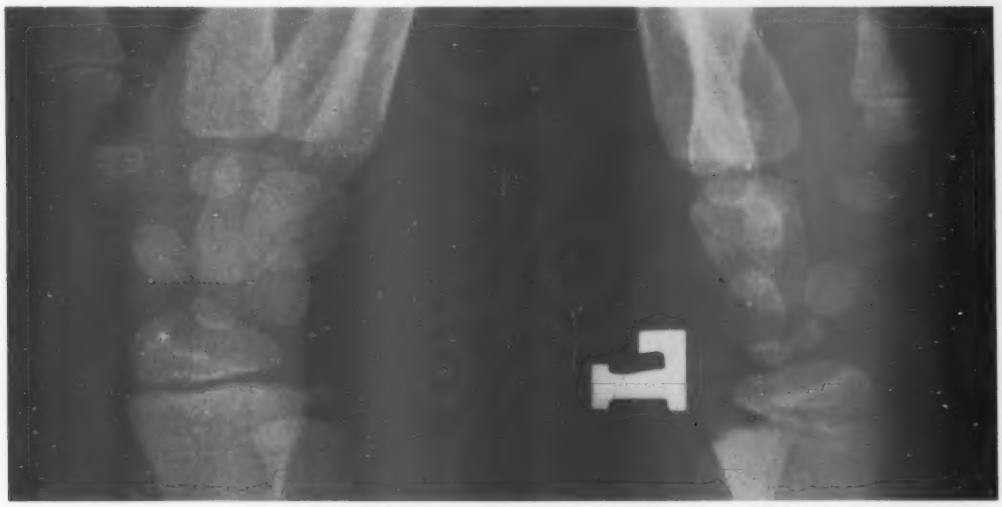

Fig. 21. Female, aged six. Two centers present for lunate, one palmar and one dorsal.

months, the multangulum majus was well marked on the left, but completely absent on the right; the lunate had just appeared on the right side, although no trace could be observed on the left. Pryor states that the order of appearance is a peculiarity of the family.

The first carpal bone to appear is usually the capitate, shortly followed by the hamate. Then follow the triquetrum, multangulum minus, lunate, multangulum majus, navicular and invariably last of all at a considerably later date, the pisiform, but there is considerable variation in the respective order of appearance of the lunate, multangula majus et minus and the navicular. In a female aged 3 months and a male aged 7 months Pryor noted the appearance of the hamate before the capitate.

NAVICULAR

Table XVII represents the incidence of appearance of the navicular bone, columns (a) showing the number of wrists examined and (b) the number of instances where centers have been found in each sex at each age group in my Australian series and in the American series of Pryor respectively.

The earliest centers noted were in a girl aged 4 years and 10 months and in a boy aged 4 years and 6 months. It was present in the majority of girls at the age of 4 and in half of the boys at the age of 5. The oldest subjects showing absence of centers were a

Table XVII

Age	Females				Males			
	Author		Pryor		Author		Pryor	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
3	6	0	9	1	13	0	3	1
4	3	3	14	7	6	1	14	1
5	3	2	30	19	12	6	39	8
6	9	9	35	30	11	9	42	20
7	8	8	14	14	26	22	10	9
8	14	14	4	4	16	15	8	6

girl aged 5 years and 5 months and a boy aged 8. Woollard states that two centers have been found for the navicular. This is of special interest in consideration of possible fractures of this bone.

Pryor found this center in a girl aged 3 years and 6 months and in a boy aged 4 years and 4 months. In his series, it was not present in a girl aged 6 years and 4 months nor in a boy aged 8 years and 3 months. His series showed the center to be present in a girl aged 4 years and 4 months, but not present in another girl aged 6 years and 4 months nor in a boy aged 8 years and 3 months, the center being found in half of the girls at the age of 4 and in the majority of boys not until the age of 7, the latter being considerably later than among the Australians.

TABLE XVIII

Age	Females				Males			
	Author		Pryor		Author		Pryor	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	9	0	3	0	5	1		
2	9	3	4	1	11	2	2	0
3	6	2	9	5	10	6	3	0
4	3	3	14	13	7	5	14	10
5	3	3	30	26	13	11	39	31
6	9	9	35	30	11	9	42	20

On one side, it was the only carpal bone absent except the pisiform.

Pryor found this center in the majority of girls aged 3 and of boys aged 4. In his series it was absent in a girl aged 6 years and 3 months.

In a girl aged 6 (see Fig. 21), and boys aged 4 years and 7 months, 5 years and 7 months and 8 years respectively, two centers, one dorsal to the other, were noted for this bone. Pryor had noted on both sides in a boy aged 6 years and 4 months both the triquetrum and lunate to be possessed of double centers.

LUNATE

Table XVIII represents the incidence of the lunate, the arrangement being the same as for the navicular in the same series of individuals.

This center sometimes appears before the triquetrum and sometimes afterwards. The youngest subjects showing this center were a boy in his second year and a girl aged 2 years and 7 months. It was found present in all girls aged 4 or over and the majority of the instances of boys aged 3. Its absence was noted in a girl aged 3 years and 5 months, in one instance on both sides, and in a boy aged 6 years and 11 months, in whom it was present on the opposite side.

OS HYPERLUNATUM

A small center immediately alongside the lunate on the ulnar side is figured by Borovansky and Hnévkovský, under the title "hyperlunatum?".

TRIQUETRUM

Table XIX represents in the same manner as the preceding, the incidence of the triquetrum.

This center is usually the earliest of the carpal bones to appear after the capitate and hamate, but may be preceded by the lunate. The earliest centers were noted in a female at the age of 1 year and 5 months and in a male at the age of 2 years and 3 months. It was found in the majority of boys aged 3 and in all girls aged 4 or over. Its absence was noted in girls at the age of 3 and in a boy aged 7 years and 3 months, in whom it was present on the left but not on the right side.

Table XIX

Age	Females				Males			
	Author		Pryor		Author		Pryor	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	11	6	3	1	3	0	2	1
2	10	1	4	3	11	4	2	0
3	7	3	9	9	13	7	3	2
4	3	3	14	14	7	6	14	11
5	3	3	30	30	13	13	39	36
6	9	9			11	11		
7	7	9			25	24		

PISIFORM

Table XX represents in the same manner as the preceding the incidence of the pisiform, and in addition columns (c) show the percentage incidence of the number of centers present as well as the incidence estimated by Paterson.

The youngest girl noted in this series with such a center was aged 7 years and 2 months and the youngest boys 7. It was present in the majority of girls at the age of 10 and in the majority of boys at 11. The oldest girl in whom it was not present was aged 10 years and 8 months and the oldest boy 14 years and 7 months.

The percentages at each age are compared with the figures given by Paterson, the latter appearing to be a rough estimate only and applicable to both sexes. In females it was present in each of 44 instances at the ages of 11 to 14, that is in 100 per cent. Thus, in this series, this bone was rather more frequently demonstrated than is estimated by Paterson, up to the age of 14 in boys and is present in all girls of the same age groups.

HAMATE

Hill has noted this center in 2 female fetuses of 36 weeks' gestation.

Except for the capitate, this is usually the first carpal bone to appear and was present in all babies of 9 months of both sexes and older, but was not present (on either side) in an infant aged 6 months, nor in male infants 1 week and 2 months old respectively. It was present in all 5 instances in babies aged 9 to 11 months. Davies and Parsons found it absent in a child aged 1 year and 3 months.

Table XX

Age	Females						Males					
	Author			Pryor			Author			Pryor		Paterson
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
7	7	1		14	1		28	2		11	0	
8	10	4		8	2		17	0		9	0	
9	7	3		4	2		9	1		8	0	
10	8	6		5	4		8	2		6	0	
11	7	7	100%	3	3	100%	14	9	57%	5	1	25%
12	16	16	100%	2	2	100%	24	16	66%	5	2	55%
13	12	12	100%				40	30	75%	3	2	80%
14	9	9	100%				50	42	84%	1	0	100%

Of 237 instances in the female and 263 in the male, within forty-eight hours after birth, Menees and Holly found this bone present 28 times (11.8 per cent) in females and 11 times (4.1 per cent) in males. The hamate was present alone (without capitate) 7 times. Adair and Scammon found it present in 5 of 45 females within 48 hours after birth.

Adair and Scammon report double centers for this bone in a female newborn of 289 days' gestation and a male newborn of 267 days' gestation.

CAPITATE

Hill has noted this center in a female fetus of 36 weeks' gestation.

The capitate is usually the first carpal bone to appear. Pryor found it present in a male child aged 2 days, and in a female aged 4 days, and from the size of these concluded that they must have been actually present before birth. However, he found the center absent in a female aged 3 months and in a male aged 7 months, although the hamate was present in each case, but it is unusual for the hamate to precede the capitate. I have noted the absence of all carpals in a male aged 1 week, but this bone was present in every instance examined of babies of 2 months and older.

Of 237 instances in the female and 263 in the male, within 48 hours after birth, Menees and Holly found this bone present in the female 31 times (13.0 per cent) and 10 times (3.8 per cent) in the male, so that its frequency does not differ very much from that of the hamate. The capitate was present alone (without the hamate) 9 times. Adair and Scammon found it present in 6 of 45 females and 9 of 55 males within 48 hours of birth.

MULTANGULUM MINUS

Table XXI represents in the same manner as those for the navicular, lunate and triquetrum, the incidence of the multangulum minus in the same series of individuals.

TABLE XXI

Age	Females				Males			
	Author		Pryor		Author		Pryor	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
3	6	1	9	1	11	2	3	0
4	3	2	14	7	7	1	14	0
5	5	5	30	24	10	4	39	9
6	9	9	33	28	10	7	41	18
7	7	7	14	14	29	26	10	7
8	12	12	4	4	15	14	8	7

The youngest girl showing this center was aged 3 years and 5 months, it being present on the right side, but absent on the left, and the youngest boy was aged 3 years and 10 months, in whom it was present on both sides. The center was present in the majority of instances in girls at the age of 4 and in boys at the age of 6. It was absent in a girl aged 4 and in a boy aged 8.

Pryor found it present in the majority of girls at the age of 4 and of boys at the age of 7, the latter being later than in the Australian series. He found it absent in a girl aged 6 years and 7 months and in a boy aged 8 years and 3 months. He also found it duplicated in a girl aged 7 years and 6 months, while Borovansky and Hnévkovský found double centers in a boy aged 5 years and 10 months.

MULTANGULUM MAJUS

Table XXII represents in the same manner as that for the multangulum minus, the incidence of appearance of this bone.

The youngest girl showing this center was aged 3 years and 5 months, the youngest boy, 5 years and 5 months. In one girl aged 3 years and 5 months, it was not present, while in a boy aged 8 it was also found absent. It was found in both instances in girls aged 4 and in the majority of boys at the age of 5.

Pryor found the center present in a boy aged 4 years and 1 month as well as in the majority of boys at the age of 7 and noted its absence in a girl aged 6 years and 7 months, and in a boy aged 8 years and 10 months.

PRIMARY CENTERS FOR METACARPAL BONES

Primary centers for each of the five metacarpal bones were noted in all fetuses of the length of 62 mm. (11½ weeks) or over in the present series (see Fig. 22).

EPIPHYSIS FOR THE FIRST METACARPAL BONE

The epiphysis for this bone, unlike those for the other metacarpels appears at the base instead of at the distal extremity (see Fig. 3). Additional centers are also frequently found for the distal extremity, in fact Borovansky and Hnévkovský estimate that 50 per cent of the boys of Prague present this epiphysis, while according to them, indications of such tendency may be noted in 70 per cent by the presence of a groove or fissure. Sometimes in the same subject additional epiphyses are also found at the bases of the other metacarpals, thus a boy aged 8 years and 6 months showed indications of these at the distal end of the first metacarpal as well as at the proximal ends of the second and fifth.

Fig. 22. Female, 165 mm. (20 weeks). Centers for vertebral bodies not united with neural arches. No centers for odontoid process of epistropheus or pubis. Middle row of phalanges present in hand but not in foot. No epiphyses, carpals or tarsals present.

Table XXIII shows the incidence of this

Table XXII

Age	Females				Males			
	Author		Pryor		Author		Pryor	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
3	6	1	9	0	11	0	3	0
4	2	2	14	6	6	0	14	5
5	4	4	30	20	11	7	39	11
6	8	8	33	26	10	7	41	15
7	7	7	14	14	27	24	10	8
8	12	12	4	4	14	13	8	6

TABLE XXIII

Age	Females				Males			
	Australian		Hindu		Australian		Egyptian	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
0	3	0			4	0		
1	8	7			5	0		
2	13	10			9	5		
3	6	6			9	7		
13	12	11			35	35		
14	4	2	24	13	48	46	110	110
15	7	3	16	6	49	43	42	28
16	14	0	12	1	40	29	101	32
17	10	0	16	3	48	27	96	10
18	21	0	9	1	41	7	71	5
19	6	0	2	0	43	2	24	0

epiphysis, columns (a) showing the number of hands examined and (b) the number of instances in which the epiphyses were present in Australian girls of my series and Hindu girls of Galstaun's series and in Australian boys of my series and Egyptian boys of the series of Sidhom and Derry respectively.

The centers were seen earliest in 2 girls aged 1 year and 2 months and in a boy aged 2 years and 3 months. It was present in the majority of girls during their second year and of boys aged 2. Its absence was noted in a girl aged 2 years and 5 months and in boys aged 3.

The youngest female in whom the epiphysis had fused was aged 13, the youngest male 14. Pryor noted fusion in a boy aged 14 years and 3 months in all five metacarpals. Union was complete in the majority of females at the age of 15 and in the majority of males at 18. Fusion had not yet taken place in girls aged 15 nor in one man aged 19 years and 7 months. In Galstaun's series, union was delayed in some Hindu girls up to the age of 18 years.

EPIPHYSES FOR SECOND, THIRD, FOURTH AND FIFTH METACARPAL BONES

The epiphyses for these usually appear, unlike those of the phalanges and first metacarpal, at the distal extremities of the second, and very rarely of the fifth. Even when such a center is not quite detached, an indication of such tendency is shown by the appearance of a constriction or fissure, instead of the usual epiphyseal interval. Epiphyses at the base of the second metacarpal were noted in a girl aged 3 and in a boy aged 7 years and 11 months. Very large epiphyses were present on each side in a boy (not included in this series) aged 9 years and 8 months, who is the subject of craniocleidodysostosis.

Table XXIV represents the incidence of the epiphyses of the second, third, fourth and fifth metacarpal bones, columns (a) representing the number of hands examined and columns (b) the number of epiphyses noted in my Australian series, Galstaun's series of Hindu girls and my series of Australian boys respectively.

The youngest subject with epiphyses for the fourth metacarpal was a girl aged 1 year and 10 months and for the fifth metacarpal 1 year and 5 months. In a female aged 1 year and 2 months, centers for the first, second and third metacarpals were present, but those for the fourth and fifth were absent. In a boy in his second year, centers were present for all metacarpals except the first. The epiphyses were present for both girls and for the majority of boys during the second year for second and third

metacarpals and in the majority of both sexes for the fourth metacarpal at the age of 2 in girls and 3 in boys. In a girl aged 2 years and 5 months and in a boy aged 2 no centers were present in any of the metacarpals, while in another boy of 3, there were none for the third, fourth and fifth.

The earliest to fuse in each of these metacarpals was in a girl aged 14 years and 9 months and in a male aged 16 years. Union takes place in the majority of girls at 16 and boys at 18 years of age. In a girl aged 17, none of the centers for these bones had fused, and in another girl aged 18, the center for the second metacarpal was still ununited. In 2 males aged 19 years, none of the centers for these metacarpal bones were united, while in another male of the same age, the center for the third metacarpal was still present although those for the second, fourth and fifth had fused with their respective diaphyses. Non-fusion with the second and third metacarpals was likewise present in a male aged 20 years and 7 months.

Pryor has found all the epiphyses for the metacarpal bones fused in the skeleton of a girl aged 14 years and 3 months.

According to the figures of Galstaun, fusion appears to be complete in the majority of instances in Hindu girls at the age of 14, that is two years earlier than is the case with the girls of the Australian series.

STYLOID PROCESS OF THIRD METACARPAL

Like Pryor, I have not met with any example of a separate epiphysis for the styloid process of the third metacarpal bone as mentioned by Cunningham and by Morris.

PRIMARY CENTERS FOR PROXIMAL PHALANGES

All fetuses of 62 mm. in length (11½ weeks) and longer showed the centers for the proximal and distal rows of phalanges already present, although those for the middle row were only found in longer fetuses (compare Figs. 7 and 22).

EPIPHYSES FOR THE PHALANGES OF THE FINGERS

Paterson's statement that the phalangeal epiphyses appear "for all practical purposes in all three rows simultaneously" is certainly not borne out by careful study, for there is a considerable variation as the following account shows. Nor are those, even in the same row, simultaneous in their appearance as a rule. Paterson likewise reports that there are no cases of epiphyses in

TABLE XXIV

Age	Females																Males							
	Author								Galstaun								Author							
	II		III		IV		V		II		III		IV		V		II		III		IV		V	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	2	2	2	2	4	1	5	2									3	2	1	1	3	1	3	1
2	11	10	10	9	11	8	10	7									7	4	7	5	8	5	8	3
3	4	4	4	4	5	5	5	5									6	6	7	7	7	7	8	7
14	4	2	2	1	5	4	5	4	24	10	24	10	24	9	24	9	26	26	26	26	31	31	34	34
15	9	5	10	7	11	6	10	6	16	7	16	7	16	7	16	7	27	27	29	29	28	28	29	29
16	11	2	10	1	10	1	9	1	12	1	12	1	12	1	12	1	24	22	25	23	23	22	22	20
17	7	1	6	1	9	1	11	1	16	4	16	4	16	4	16	4	30	19	31	21	31	24	33	25
18	20	1	19	0	17	0	21	0	9	1	9	1	9	1	9	1	33	7	32	7	25	8	32	7
19	3	0	3	0	4	0	4	0	3	0	3	0	3	0	3	0	31	3	33	3	28	2	32	2
20	9	0	10	0	11	0	13	0									20	1	20	1	21	0	21	0

TABLE XXV

Age	Females		Males	
	(a)	(b)	(a)	(b)
1	2	1	4	0
2	11	7	7	0
13	8	6	17	17
14	3	2	32	29
15	8	3	32	27
16	9	0	24	13
17	14	0	30	14
18	19	0	30	4
19	2	0	33	4

males before the third year, but in this series, those for the proximal phalanges of the index, middle, ring and little fingers, as well as that for the distal phalanx of the thumb are noted in both sexes during the second year.

EPIPHYSIS FOR PROXIMAL PHALANX OF THE THUMB

Table XXV gives the incidence of the appearance of the epiphysis at the base of the proximal phalanx of the thumb, columns (a) representing the number of thumbs examined and columns (b) the number of epiphyses noted.

The earliest epiphyseal centers to appear were in a girl aged 1 year and 11 months and in a boy aged 3 years and 10 months. It was found in all 7 instances at 3 years of age. It was absent in a girl aged 2 years and 5 months, although the epiphyses for all the other proximal phalanges were present, nor was it present in a boy aged 2 years and 6 months. Its presence was noted in the majority of instances in girls at the age of 2.

The earliest centers to fuse were in a girl aged 13 years and 8 months and in a boy aged 14. Fusion was complete in the majority of the instances in girls at the age of 15 and of boys at 17 years of age. The latest unfused were in a girl aged 15 years and 6 months and in a man aged 19 years and 11 months, in whom all the other epiphyseal centers of the row were found fused.

EPIPHYSES FOR PROXIMAL PHALANGES OF THE INDEX, MIDDLE, RING AND LITTLE FINGERS

Table XXVI represents the incidence of the epiphyses at the bases of the proximal phalanges for the index, middle, ring and little fingers, columns (a) showing the number of fingers examined and columns (b) the number of epiphyses noted at each age in each sex respectively.

These centers all appear considerably earlier than in the case of that of the

TABLE XXVI

Age	Females								Males							
	II		III		IV		V		II		III		IV		V	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
0	0	0	1	1	2	2	2	0	0	0	2	0	2	0	1	0
1	4	4	3	3	3	3	4	3	3	2	2	2	2	2	3	2
2	9	9	8	9	9	9	6	6	6	5	6	5	7	6	7	5
3	4	4	4	4	4	4	4	4	3	3	4	4	5	4	5	4
13	6	5	8	7	7	7	7	6	8	8	6	6	7	7	9	9
14	5	4	3	1	4	2	4	2	21	19	19	18	21	20	23	22
15	10	7	11	5	10	4	7	3	24	20	23	20	25	22	25	23
16	7	1	11	1	11	2	9	1	23	19	23	19	20	17	21	18
17	6	0	4	0	2	0	9	0	30	16	31	18	31	16	26	17
18	19	0	16	0	17	0	17	0	29	5	33	5	32	4	27	4
19	3	0	3	0	3	0	2	0	30	3	30	2	32	2	32	2

TABLE XXVII

Age	Females								Males							
	II		III		IV		V		II		III		IV		V	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	3	1	2	1	2	1	3	1	3	0	2	0	2	0	2	0
2	4	3	4	3	4	3	2	1	4	1	4	1	5	1	3	0
3	1	1	1	1	1	1	2	1	0	0	2	2	1	1	0	0
13	4	3	4	4	5	5	4	4	7	7	6	6	5	5	5	5
14	4	2	4	3	4	3	3	2	19	17	17	16	17	16	17	16
15	7	5	7	6	6	5	6	4	14	10	14	11	14	11	16	31
16	3	0	8	1	7	1	4	0	19	13	21	15	15	11	12	9
17	2	0	3	0	2	0	3	0	17	6	18	7	20	9	18	9
18	14	0	13	0	12	0	13	0	21	2	24	2	22	4	23	3
19	1	0	1	0	0	0	2	0	25	3	29	2	26	2	26	2

thumb. The youngest female to show centers for these was aged 10 months, in whom they were present in the middle finger of the left hand and ring fingers of both hands, but absent in the little fingers on both sides. The earliest centers for all four digits had appeared in a girl aged 1 year and 2 months and in a boy in his second year. In another boy aged 2, although those for the middle and ring fingers were present, the center for the index and little fingers had not yet appeared.

Davies and Parsons found centers present in all digits in a child (sex not stated) aged 9 months.

In the majority of children of both sexes, centers had appeared in all four phalanges during their second year. In every instance centers were found in girls over the age of 10 months except in a girl of 1 year and 6 months, in whom all were present except that for the index, while in another boy aged 3, the centers for the ring and little fingers had not yet appeared. The youngest subjects with fused epiphyses were a girl aged 13 years and 9 months in the case of the index and middle fingers and a girl aged 13 in the case of the little finger. In a girl aged 14 years and 9 months, they were fused in all four digits. In the majority of girls, fusion was completed for the middle finger at the age of 14, and in half of the girls at the same age for the ring and little fingers, while for the index finger union was complete in the majority at the age of 16. For boys fusion took place in the majority at the age of 18 for all four digits. In a girl aged 16, fusion had not yet occurred in any of the four proximal phalanges. In a man aged 19, likewise none was fused while in one man aged 19 years and 7 months, the center for the phalanx for the index finger was still present.

Pryor found all the centers for the phalanges fused in a girl aged 14 years and 3 months.

PRIMARY CENTERS FOR MIDDLE ROW OF PHALANGES

Table XXVII represents the incidence of the epiphyses at the bases of the middle row of phalanges, the arrangement being the same as that for the preceding table for the corresponding row of proximal phalanges.

The earliest centers to appear were in a female aged 1 year and 2 months, in whom it was present in the little finger and 1 year and 11 months in whom it was present in the index, middle and ring fingers but not in the little finger, also in a boy aged 2 years and 3 months in whom it was noted in all four digits. The oldest girls without epiphyses for the index, middle and ring fingers were aged 2 years and 5 months and for the

little finger 3 years and 5 months, while the oldest boys were aged 2 years for the index and middle fingers and 2 years and 6 months for the ring and little fingers. That

TABLE XXVIII

Age	Females				Males	
	Author		Author		Sidhom and Derry	
	(a)	(b)	(a)	(b)	(a)	(b)
0	1	1	4	0		
1	4	2	3	1		
2	8	8	6	4		
13	4	2	6	6		
14	3	1	17	14	102	86
15	7	2	17	17	40	15
16	6	0	10	8	95	15
17	4	0	26	8	90	9
18	15	0	19	1	70	3
19	3	0	31	3		

for the little finger had not yet appeared in a girl aged 3 years and 5 months. In general, the centers were present in the majority of girls at the age of 2 for the index, middle and ring fingers and in all boys at the age of 4, but insufficient material is available for this particular study.

In the case of the index finger, the youngest girl with fused epiphysis was aged 13 years and 8 months. In a boy aged 14, the centers for the index, ring and little fingers had fused, although that for the middle had not yet united. The youngest boy with fused center for the middle finger was aged 15 years and 11 months. In a girl aged 14 years and 9 months, all four epiphyses were fused, while the oldest girls with unfused centers for the middle and ring fingers were aged 16 and for the index 15 years and 1 month, and in a girl aged 15 years and 11 months those for the middle, ring and little fingers had not yet fused. The oldest males with unfused centers were aged 19 in whom they were present in the whole row. The majority of centers unite at the age of 16 in females and 17 in males.

Pryor found all the centers for the phalanges fused in a girl aged 14 years and 3 months.

PRIMARY CENTERS FOR DISTAL PHALANGES

Like those of the proximal row and the long bones in general, the primary centers for the distal row of phalanges were seen in all fetuses of a length of 62 mm. (11½ weeks) or over, that is earlier than those for the middle row (see Fig. 7).

EPIPHYSIS FOR DISTAL PHALANX OF THUMB

Table XXVIII represents the incidence of the epiphysis at distal phalanx of thumb, columns (a) showing the number of thumbs examined and columns (b) the number of epiphyses noted in my Australian series as well as of the series of Egyptian boys of Sidhom and Derry.

The youngest subject with a center for this epiphysis was a female infant aged 10 months, in whom the centers were also present for the bases of the proximal phalanges of the middle and ring fingers. It was also seen in a male infant 1 year old, in whom none of the epiphyses for the middle row were present, although in all of the proximal row except that for the thumb and all of the metacarpals except the first. The center had not yet appeared in a female child 1 year and 10 months old nor in a male aged 2.

The earliest centers to fuse were at the age of 13 years and 8 months in a girl and 14 in a boy. Half had fused at the age of 13 in females and the majority at 17 in males. The oldest female with unfused epiphysis was aged 15 and the oldest male 19 years and seven months.

Sidhom and Derry found fusion to take place in the majority of Egyptian boys at the age of 15, that is two years earlier than in the Australian series.

EPIPHYSES FOR DISTAL PHALANGES OF INDEX, MIDDLE, RING AND LITTLE FINGERS

Table XXIX represents the incidence of the epiphyses at the bases of the distal pha-

langes of the index, middle, ring and little fingers, the arrangement being the same as those for the preceding tables for the corresponding rows of proximal and middle phalanges.

In a girl aged 1 year and 11 months, the centers were present in the middle and ring fingers but absent in the index and little fingers. In a boy aged 2, the epiphyseal center was present in the index finger on one side only, but absent on the other side as well as in all other distal phalanges on both sides. In a girl aged 3 years and 5 months, centers were present for the whole row. One child aged 3 showed no epiphyses in any of these fingers. In a boy aged 2 years and 6 months, the center for the ring finger had not yet appeared.

In a boy aged 14 years and 9 months, the centers for the index, middle and ring fingers had fused. In a boy aged 14, the centers for all these phalanges had united. In a girl aged 15 years and 6 months, the centers were fused in the case of all the digits. In the female the majority of the epiphyses fuse at the age of 15, in the male at 16 for the middle finger and 17 for the index, ring and little fingers. Thus, it appears that the center for the middle finger fuses at an earlier date than the others in the male at least. Unfused epiphyses were present for all fingers at the age of 15 in a female and for the ring finger in a girl aged 16, while the oldest male with non-fusion for all the distal phalanges (both sides) was aged 17.

Pryor found all the centers for the phalanges fused in a girl aged 14 years and 3 months.

SESAMOID OSSICLES

Sesamoid ossicles, usually two, are practically constantly found over the heads of the first metacarpal bones in the palmar aspect. Similar ossicles, usually single, are generally, but not invariably, found over the heads of the second metacarpal on the radial side and the fifth metacarpal bone on the ulnar aspect, but similar ossicles over the third and fourth are rather rare. Usually, also, very much smaller ossicles are present in the tendon of the flexor longus pollicis beneath the head of the proximal phalanx of the thumb, and these are always single.

PROXIMAL SESAMOID BONES OF THUMB

Table xxx represents the incidence of the presence of the proximal sesamoid of the

Table XXIX

Age	Females								Males							
	II		III		IV		V		II		III		IV		V	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	3	0	4	2	2	1	2	0	0	0	0	0	0	0	0	0
2	0	0	0	0	1	1	0	0	2	1	2	0	3	0	3	0
14	3	1	4	2	4	2	3	3	15	14	12	11	13	12	13	12
15	7	3	7	2	8	2	6	2	8	5	8	6	9	8	10	8
16	6	0	7	0	7	1	4	0	8	5	12	5	9	8	9	7
17	4	0	2	0	3	0	4	0	15	6	15	6	17	6	17	7

Table XXX

Age	Females		Males	
	(a)	(b)	(a)	(b)
9	2	1	5	0
10	3	2	1	0
11	4	3	5	0
12	6	2	9	1
13	3	3	4	2
14	3	3	15	14
15	8	8	24	23

FIG. 23. Male, aged twenty-one. Sesamoids present over heads of all metacarpals.

thumb, columns (a) representing the number of thumbs examined and columns (b) the number of instances in which these ossicles have been observed at each age in each sex.

The earliest centers were noted in a girl aged 9 years and 5 months on one side at least and a boy aged 12 years and 8 months on both sides, the majority of girls aged 13 and half the boys of the same age showing sesamoids. It was absent in girls aged 12 and also absent in a boy aged 15. It was likewise noted absent in a subject aged 17 of unknown sex.

SESAMOID OF INDEX FINGER

As before, Table XXXI represents the incidence of the sesamoid for the index finger, columns (a) representing the number of these digits examined and columns (b) the number in which such sesamoids have been observed.

The earliest examples were noted in a girl aged 11 years and 6 months and in boys aged 14. It is present in half of the instances in girls at 15 and in the majority of males at 19. However, it is commonly absent at a much later date; thus, it was not present on

TABLE XXXI

Age	Females		Males	
	(a)	(b)	(a)	(b)
11	4	1	1	0
12	5	1	5	0
13	3	0	1	0
14	2	0	10	3
15	6	3	10	2
16	4	4	10	6
17	3	3	11	3
18	5	1	17	5
19	3	1	18	11
20	6	5	12	5
21	2	2	16	12
22	3	2	11	5
23	6	3	10	9
24	1	1	9	6
25	0	0	4	2
26	0	0	1	0
27	0	0	2	0
28	0	0	1	1

either side in a female of 23 although present over the fifth metacarpals, nor was it present in a male aged 27. Older subjects were not studied, but it is likely that in certain individuals it may never occur.

SESAMOIDS OF MIDDLE AND RING FINGERS

These are rare. In the middle finger, instances were noted in a girl aged 13 years and 10 months and in a boy aged 14 years and 0 months. In a man aged 21 (see Fig. 23) sesamoid bones were present at the heads of all the metacarpals, those for the middle and ring fingers being on the radial aspects, while two were present for the fifth metacarpal. In another subject of the same age of unknown sex, a very large sesamoid appeared to be situated over the middle of the head of the third metacarpal bone.

SESAMOID OF THE LITTLE FINGER

As before, Table XXXII represents the incidence of the sesamoid for the little finger, columns (a) representing the number of these digits examined and columns (b) the number in which such sesamoids have been observed.

The earliest examples were seen at the age of 13 years and 10 months in the female and 14 years in a male. At the age of 15 in the female and 17 in the male the majority showed presence of these ossicles. However, instances were found at the age of 23 in the female and 27 in the male in whom they were not present.

TABLE XXXII

Age	Females		Males	
	(a)	(b)	(a)	(b)
13	6	1	1	0
14	1	1	11	1
15	6	4	14	5
16	4	4	11	5
17	4	4	15	8
18	4	3	24	14
19	3	2	16	11
20	9	9	10	6
21	3	3	14	13
22	6	5	14	10
23	7	5	13	13
24	3	3	8	6
25	0	0	7	5
26	0	0	4	2
27	0	0	1	0

TABLE XXXIII

Age	Females		Males	
	(a)	(b)	(a)	(b)
14	1	1	3	0
15	0	0	8	2
16	3	3	4	2
17	2	2	7	5
18	5	5	8	5
19	1	0	10	8
20	3	2	4	4
21	0	0	8	7
22	1	1	3	2
23	0	0	7	5
24	0	0	5	2
25	0	0	2	1

DISTAL SESAMOID OF THE THUMB

Again, as before, Table XXXIII represents the incidence of the sesamoid over the head of the proximal phalanx of the thumb, columns (a) representing the number of thumbs examined and columns (b) the number in which such sesamoids have been observed.

This is a very small ossicle found at the head of the proximal phalanx of the thumb near the insertion of the tendon of the flexor longus pollicis into the base of the distal phalanx.

The earliest sesamoids were seen at the age of 14 years and 9 months in a girl and 15 in boys. The majority of females aged 16 and half of the males aged 16 showed its presence. Examples of absence were noted at the age of 20 in the female and 25 years and 2 months in the male.

EARLIEST PRIMARY CENTERS FOR LOWER LIMB

The primary centers for the ilium, femur, tibia and fibula were all present in a fetus of 32.5 mm. (49 days after single coitus), as well as in all larger fetuses (Fig. 7). Although the centers for the distal phalanges

TABLE XXXIV

Age	Females		Males	
	(a)	(b)	(a)	(b)
10	5	2	12	0
11	17	2	18	0
12	7	1	17	0
13	6	4	11	5
14	8	8	14	4
15	13	13	22	14
16	18	17	12	9
17	10	10	29	25

of the hallux were not present in a female fetus of 62 mm. (11½ weeks) these were found in all fetuses of 70 mm. (12 weeks) or over. The centers for the metatarsals and proximal row of phalanges were, however, present in the 62 mm. fetus, as well as in all larger fetuses.

PRIMARY CENTERS FOR THE OS COXAE

The ilium was present in all fetuses of 32.5 mm. (49 days) and older (see Fig. 7) and the ischium in those of 109 mm. (15 weeks) and longer, while the os pubis, which appeared considerably later was first noted in a male fetus of 165 mm. (20 weeks) and in a female of 205 mm. (23 weeks), although absent in a male of 180 mm. (21 weeks) (see Fig. 11).

CENTERS OF OSSIFICATION IN Y-SHAPED CARTILAGE

One or more centers of ossification are usually present in the Y-shaped cartilage in the floor of the acetabulum, but the precise roentgenographic demonstration of these presents considerable difficulties.

UNION OF CENTERS FOR ILIUM, ISCHIUM AND PUBIS

Table XXXIV represents the incidence of fusion of the three primary centers for the ilium, ischium and pubis, columns (a) indicating the number of hips examined and columns (b) the number of instances in which these centers have fused with each other.

The youngest girl in whom the cartilaginous junction (Y-shaped cartilage) of the three component parts of the os coxae had completely ossified was aged 10 years and 6 months and the youngest boy 13 years and 7 months (in each case on both sides). Fusion had taken place in the majority of the girls at the age of 13 and of boys not until 15 years of age. The oldest subjects with unfused centers were a girl aged 16 years and 10 months and a boy aged 17 years and 11 months.

EPIPHYSIS FOR ACETABULAR MARGIN

Morrison describes and illustrates separate centers of ossification on the supero-anterior, superior and supero-posterior aspects, respectively, of the rim of the acetabuli, which, when ossified, serve to deepen the cavity. The superior is first noted in a boy at the age of 12, in whom it was present on the left but not on the right. In the same boy, it was present on both sides at the age of 12 years and 3 months and at 13 years and 2 months showed two centers on the left and only one on the right. At 13 years and 6 months, the right center had fused and at 14 years and 4 months, the left center likewise disappeared. The right hip is the site of tuberculous disease, probably accounting in part for the change. In another boy, the subject of multiple osteomyelitis, at 13 years and 6 months, a center is shown for the left postero-superior acetabular rim, but not until 14 years and 8 months, when the left epiphysis is "nearly closed" is a similar center noted on the right side, which is still present at the age of 16 years. In a third boy aged 14, well defined epiphyses were noted on the posteroanterior margin of both acetabula.

Morrison states that frequently separate permanent ossicles are found on the anterior, superior and posterior aspects, respectively, of the acetabular rim. However, it is exceptional for epiphyses in other regions to persist throughout life as permanent and independent ossicles.

In the present series, a detached ossicle was noted on the acetabular margin on each

side below the anterior inferior spine in a boy aged 15 years and 3 months.

Under the name os acetabuli, Freedman illustrates similar centers on the superolateral aspect of the acetabular margin, in each case bilateral in two subjects aged 14 and 26 respectively.

UNION OF ASCENDING ISCHIAL WITH DESCENDING PUBIC RAMUS

Table XXXV represents the incidence of fusion of the ascending ramus of the ischium with the descending ramus of the pubis, columns (a) indicating the number of pelves examined, and (b) the number of instances in which these rami had fused at each age group in each sex respectively.

The youngest girl showing fusion of the rami was aged 3 years and 11 months, the youngest boy 4 years and 0 months, on both sides in each case. The majority showed union at the age of 8 in girls and 7 in boys. Davies and Parsons noted fusion in a boy aged 3. In a boy aged 11 years and 4 months, union was not complete on either side, but in a girl of 11, fusion was present on one side, but not on the other.

EPIPHYSIS FOR ILIAC CREST

Table XXXVI shows the incidence of the presence of one or more epiphyseal centers along the iliac crest, columns (a) indicating the number of pelves examined and (b) the number of instances in which the epiphyses were noted.

TABLE XXXV

Age	Females		Males	
	(a)	(b)	(a)	(b)
3	17	2	22	0
4	14	2	26	2
5	10	4	31	11
6	1	0	11	2
7	10	4	24	13
8	9	8	12	7
9	13	13	9	6
10	4	1	12	10
11	12	11	16	12

TABLE XXXVI

Age	Females		Males	
	(a)	(b)	(a)	(b)
12	11	2	7	0
13	11	2	10	4
14	10	9	11	0
15	19	19	11	4
16	24	24	11	6
17	20	14	29	18
18	46	44	24	18
19	18	11	35	28
20	32	25	16	10
21	23	9	26	6
22	25	5	16	3

The youngest subjects in whom these epiphyses were present were a girl aged 12 years and 0 months and a boy aged 13 years and 4 months in whom it was present on each side in each case. Cleaves reports epiphyses well developed in a boy of only 12 years. In females the majority of epiphyses appear at the age of 14 and in males at 16 years of age, but the maximum incidence is at 15 and 16 in girls and 19 in young men. Epiphyses were present in the female at the age of 22 years and 3 months and in the male at the age of 22 years and 9 months. The majority were fused at the age of twenty-one in both sexes.

SYMPHYSIS PUBIS

An epiphysis for the symphysis pubis, such as is usually described, has not been found in this series, nor can a description of such as actually observed in the roentgenogram be discovered in the literarure, so that either it does not exist at all or it is exceedingly rare. The symphysis pubis is very favorably situated for examination, so that if such were actually present, it could scarcely escape recognition. Similarly no trace of any epiphysis about the pubic crest or pubic spine has yet been met with.

Burman, Weinkle and Langsam, in a roentgenological study of the development of the symphysis pubis, make no reference to the presence of any epiphysis in this region.

EPIPHYSIS FOR THE ANTERIOR SUPERIOR ILIAC SPINE

This appears to be a rare epiphysis and in this series was met with only three times, on each occasion in females aged 13 years and 5 months, 14 and 17 years respectively,

FIG. 24. Female, aged seventeen. Epiphysis for anterior superior iliac spine. (Courtesy of the *Journal of Anatomy*.)

in one of them at least, it was present on both sides (see Fig. 24). Possibly this epiphysis might be considered a separate fragment of the epiphysis for the iliac crest.

ANTERIOR INFERIOR ILIAC SPINE

Morrison illustrates what he describes as a "normal epiphysis of the anterior inferior iliac spine," but the age and sex are not given, and the subject appears to be an adult. I have never seen a roentgenographic demonstration of an undoubted epiphysis for the anterior inferior iliac spine. However, such would be in a difficult situation for such a study.

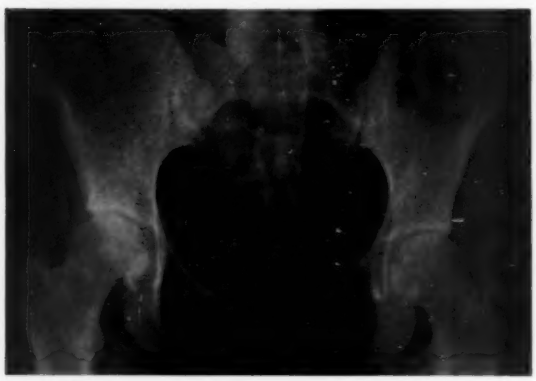

FIG. 25. Female, aged twenty. Note epiphyses along perineal margins anterior to ischial tuberosities. Centers for iliac crests not yet fused.

EPIPHYSIS OVER THE TUBER ISCHII

The epiphysis for this process forms a thin scale along the ascending ramus of the ischium (see Fig. 25) and descending ramus of the pubis even as far as the apex of the perineal arch. This is the epiphysis described by Stevenson as the ramal epiphysis which he regards as distinct from that of the tuber ischii.

Table XXXVII represents the incidence of the presence of this epiphysis, columns (a) indicating the number of pelves examined, and (b) the number of centers observed at each age group in each sex respectively.

TABLE XXXVII

Age	Females		Males	
	(a)	(b)	(a)	(b)
13	4	2	9	2
14	7	2	14	0
15	2	0	18	3
16	9	8	12	0
17	5	2	25	9
18	21	16	15	6
19	7	6	23	14
20	32	26	10	2
21	12	6	19	3
22	24	2	9	0
23	15	0	11	0
24	21	2	17	0

The youngest girl in whom this epiphysis was found was aged 13 years and 5 months, and the youngest boy 13, in each case being present on both sides. Table XXXVII appears to indicate that the epiphysis is present in the majority of females at the age of 16 and of males at the age of 19. The maximum incidence is between the ages of 16 and 20 in females and 19 in males. Fusion is present in the majority of males at the age of 20 and of females at the age of 21. It seems to be more than twice as frequently demonstrable relatively between the ages of 13 and 24 inclusive in females (72 times in 159 instances, or 45.3 per cent) than in males (39 times in 182 instances, or 21.1 per cent). It was noted on both sides in a female aged 24 and in a male aged 21.

PRIMARY CENTER FOR HEAD OF FEMUR

This was noted in all fetuses of 32.5 mm. (49 days) or longer (see Fig. 7).

EPIPHYSIS FOR HEAD OF FEMUR

The incidence of the presence of this center is represented by Table XXXVIII, columns (a) indicating the number of hips examined and (b) the number of instances in which these epiphyses are noted to be present.

TABLE XXXVIII

Age	Females		Males	
	(a)	(b)	(a)	(b)
0	14	12	19	9
13	6	4	13	13
14	10	2	14	13
15	7	0	18	15
16	14	2	12	7
17	7	0	24	10
18	21	1	19	2
19	11	0	27	0
20	29	0	10	2

Of 237 instances in females and 263 in males within 48 hours after birth, Menees and Holly found this center present twice only in females (0.8 per cent) and once in a male (0.3 per cent).

The epiphysis for the head of the femur apparently always appears during the first year after birth except in those rare instances in which it appears just before birth. It was present in a male infant and in a girl aged 9 months, in each case on both sides, but in each of 2 boys aged 9 months, it was present on the right side, although absent on the left. It was not present on either side in a girl aged 2 months nor in a boy aged 3 months. In all of 25 instances in girls and 17 in boys in their second year this center was found to be present.

The youngest subjects in whom this epiphysis had fused were a girl aged 13 years and 4 months and a boy aged 14, in the former instance on both sides. At the age of 14, the great majority had fused in girls, but not until the age of 17 in males had the majority united. This is much earlier than the dates given by Paterson, namely 17 for females and 18 for males. The oldest subjects with unfused epiphyses were 18 years and 2 months in a female and 20 years and 2 months in a male (both sides).

TABLE XXXIX

Age	Females		Males	
	(a)	(b)	(a)	(b)
2	18	4	16	0
3	16	10	20	0
4	14	8	22	7
5	11	11	28	21
6	6	6	6	4
14	8	0	13	13
15	2	0	14	10
16	6	1	6	4
17	5	0	19	8

EPIPHYSIS FOR GREATER TROCHANTER

Table XXXIX represents the incidence of the presence of the epiphysis for the greater trochanter, columns (a) indicating the number of hips examined and (b) the number of instances in which these epiphyses were observed at each age group in each sex respectively.

The youngest girl with a center for the greater trochanter was aged 2 years and 7 months in whom it was present on both sides, while the youngest boys were aged 4 years and 4 months. The majority of epiphyses appeared at the age of 3 in girls and 5 years in boys. Borovansky and Hnévkovský found this center present in a boy aged 3 years and 5 months. The oldest girls in whom the epiphyses had not yet appeared on either side were aged 4, while in a boy of 6 the epiphyses were likewise absent on both sides.

The earliest to fuse were in a girl aged 14 years and 4 months and in a boy of 15 years and 10 months. The majority were fused in girls at the age of 14 and in boys at 18. Union had not yet taken place on either side in a girl aged 16 years and 10 months nor in a boy aged 17 years and 6 months.

TABLE XL

Age	Females		Males	
	(a)	(b)	(a)	(b)
8	8	0	11	1
9	11	6	12	1
10	0	0	13	3
11	12	4	14	2
12	7	0	11	6
13	4	0	6	0
14	6	0	15	13
15	4	0	15	12
16	7	1	10	4
17	5	0	20	6

Morrison illustrates a second epiphysis situated at the highest part of the epiphysis for the greater trochanter in two subjects aged 9 and 10 years respectively, but does not mention in which sex. He likewise shows illustrations of a number of instances of separate ossicles in this same position.

EPIPHYSIS FOR LESSER TROCHANTER

Table XL illustrates the incidence of occurrence of the epiphysis for the lesser trochanter, columns (a) indicating the number of hips examined and (b) the number of epiphyses observed at each age group in each sex respectively.

The youngest girl with epiphysis for this process was aged 9 years in whom it was present on the right but not on the left and the youngest boy 8 years and 11 months. At the age of 14 it was present in boys in the great majority of cases. The maximum incidence was in girls at the age of 9 and in boys at the age of 14. Although the center was present in 48 of 127 (37.8 per cent) instances in boys aged 9 to 17, it was only noted 11 times in 64 instances (17.2 per cent) in girls of the same ages. It seems probable that this center is not constantly present and perhaps is much more common in boys than in girls. The center was found present in a girl aged 16 years and 10 months and in a boy aged 17 years and 11 months.

DISTAL FEMORAL EPIPHYSIS

Probably the distal femoral epiphysis is the first epiphysis to appear in the human subject and was noted earliest in a female of 262 mm. and in a male of 263 mm. (both 30 weeks) in length. It was still absent, however, in a female of 280 and in a male of 283 mm. (each 32 weeks). It was found present in all 11 fetuses of 294 mm. (33 weeks) and longer, as well as in all 14 instances in babies examined during the first year after birth.

Hill recorded this center in a male fetus estimated at 24 weeks, although absent in 40 other males and 33 females of the same estimated age. He also found it in a female aged 28 weeks (estimated).

Pryor noted the presence of epiphyses in each of two females within 2 days after premature birth at 8 months, but it was not present in a male under similar circumstances. Of 48 girls and 43 boys examined during the first 9 days after birth, this epiphysis was present in every instance except in 2 boys.

Hill found this center in all of 35 females and 47 of 50 male full time fetuses.

Of 237 instances in females and 263 in males within 48 hours after birth, Menees and Holly found this center present in all except 1 female (99.6 per cent) and 4 males (98.4 per cent).

Adair and Scammon found this center in all of 45 females and 55 males within 48 hours after birth except in a female and a male, both of whom were frankly premature.

In obstetric practice the roentgenographic demonstration of the presence of this epiphysis gives some clue to the period of gestation.

Table XLI gives the incidence of this

TABLE XLI

Age	Females		Males	
	(a)	(b)	(a)	(b)
14	5	4	8	8
15	5	2	9	9
16	11	8	12	10
17	6	0	17	11
18	10	1	13	8
19	4	1	12	1

epiphysis, columns (a) indicating the number of knees examined, and (b) the number of instances in which these have been observed at each age group in each sex respectively.

The youngest girl in whom this epiphysis had fused was aged 14, the youngest boys 16. The center was fused in the majority of females at the age of 17 and in the majority of males at 19. Instances of non-fusion were met with in both sexes at the age of 19.

CENTER FOR PATELLA

The patella is best demonstrated in young children in the lateral view of the knee joint (Fig. 26), for its absence cannot always be definitely determined in the posteroanterior view as the early nucleus may be obscured behind the shadow of the lower extremity of the femur.

Sometimes an additional center on the upper and outer aspect is present. This forms the patella bipartita or patellula. Borovansky and Hnévkovský found one in a boy aged 14. In this series an example was seen in a female aged 27 years and 6 months. Borovansky and Hnévkovský also show an illustration of a separate ossicle at the apex of the patella in a boy aged 16 years and 11 months.

Table XLII represents the incidence of occurrence of the center for the patella, columns (a) indicating the number of knees examined in my series of Australian girls and boys and the series of Swedish girls and boys of Hellmer respectively, and (b) the number of instances in which these centers were found in the same series.

Fig. 26. Male, aged six years eight months. Tongue-shaped process for anterior tubercle of tibia not yet appeared.

The youngest girl showing a center for the patella was aged 2 years and 6 months, the youngest boy 3 years and 11 months. It was present in half of the girls from the age of 2 and the majority of boys at the age of 5. In a girl aged 3 years and a boy aged 8, the bone had not yet appeared. Borovansky and Hnévkovský found a center present in a boy aged 3 years and 7 months.

Table XLII

Age	Females				Males			
	Author		Hellmer		Author		Hellmer	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
2	10	5	12	0	8	0	14	0
3	2	1	17	6	8	2	17	0
4	1	1	13	11	6	2	13	3
5	6	6	14	14	5	4	14	10
6	1	1	17	17	4	4	17	17
7	2	2	19	19	9	9	19	19
8	1	1	22	22	7	6	22	22

FIG. 27. Female, aged twenty-nine. Note fabella.

Hellmer found in a girl aged 1 year and 11 months a center present on the left, but absent on the right. Six months later in the same subject, they were present on both sides. In the larger Swedish series of Hellmer, the center was present in the majority of girls aged 4 and of boys aged 5.

FABELLA (SEE FIG. 27)

Table XLIII represents the incidence of the presence of the fabella, columns (a) indicating the number of knees examined, and columns (b) the number of instances in which this sesamoid has been observed.

Of this series, the youngest female showing this sesamoid bone was aged 17, the youngest male being 16 years and 5 months of age. It is by no means common, for of 176 individuals aged 16 to 29, it was present only 15 times, or 8.5 per cent.

I have learned of an instance where this ossicle was surgically removed under the impression that it was a pathological foreign body.

PRIMARY CENTER FOR TIBIA

As for the femur and fibula, all fetuses of 32.5 mm. (49 days) and longer showed the primary center for the tibia already present (see Fig. 7).

PROXIMAL EPIPHYSIS OF THE TIBIA

The proximal tibial epiphysis is second in order of appearance only to that of the distal femoral epiphysis, being first noted in a female of 294 mm. (33 weeks) and in a male also of 294 mm., but was absent in a female of 324 mm. (37 weeks) and in a male 334 mm. (38 weeks) in length. It was present in every one of 14 instances in babies during the first year after birth.

Hill noted this center in a fetus of estimated age of 32 weeks.

Pryor noted this center present 2 days after premature birth at 8 months in a female, but it was absent in a male and in a female after premature birth at 8 months. Of 47 female and 42 male infants in the first 9 days after birth, this center was noted absent in 7 females and 13 males, being relatively twice as frequently absent in boys as in girls. Its absence was also noted in a girl aged 23 days.

Adair and Scammon report its presence in 37 of 45 females and 42 of 54 males within 48 hours after birth.

Of 35 female and 49 male full time fetuses, Hill recorded the presence of this epiphysis in 25 and 32 respectively.

Menees and Holly noted its presence in 191 females and 212 males (80.6 per cent of each sex) in 237 instances in girls and 263 in boys within 48 hours after birth.

TABLE XLIII

Age	Females		Males	
	(a)	(b)	(a)	(b)
16	5	0	9	2
17	6	1	13	1
18	6	1	7	0
19	4	0	9	1
20	6	1	4	1
21	7	1	19	3
22	6	0	13	0
23	8	0	10	1
24	4	0	9	0
25	0	0	5	0
26	0	0	4	0
28	2	0	2	0
29	0	0	1	0

Table XLIV represents the incidence of occurrence of this epiphysis, columns (a) indicating the number of knees examined and (b) the number of centers observed at each age group in each sex respectively.

The tongue-shaped prolongation which forms the anterior tubercle is not usually present until after the age of 8 (see Figs. 26 and 28). Usually it is an extension of the proximal epiphysis forward over the upper

Table XLIV

Age	Females		Males	
	(a)	(b)	(a)	(b)
14	6	5	8	8
15	5	2	9	9
16	7	3	10	8
17	7	1	17	11
18	12	1	12	4
19	4	1	16	2

end of the diaphysis. Sometimes an additional center is present over this process. One such was found in a girl aged 10 years and 6 months, in whom no trace of a tongue-shaped process had yet appeared.

The earliest to fuse were in a girl aged 14 and in a boy aged 16 (both sides). Although the center had disappeared in the majority of girls at the age of 15, it was not until the age of 18 that the majority of epiphyses in boys had united. Instances of non-fusion were found in both sexes at the age of 19.

PRIMARY CENTER FOR FIBULA

As in the case of the femur and the tibia, a primary center for the fibula was seen in every fetus of 32.5 mm. (49 days) or longer.

PROXIMAL EPIPHYSIS OF FIBULA

Table XLV represents the incidence of occurrence of the proximal epiphysis of the fibula, columns (a) indicating the number of knees examined and (b) the number of such epiphyses noted at each age group and in each sex respectively.

The earliest centers were in a girl aged 2 years and 11 months and in a boy aged 3 years and 4 months, in each case on both

Fig. 28. Age eighteen. Large hiatus behind tongue-shaped process of anterior tubercle is present on both sides and is probably not of traumatic origin.

sides. It was present in the majority of girls at the age of 3 and of boys at 5. Its absence was noted in a girl aged 4 and in a boy aged 5.

The earliest epiphyses to fuse were in a

Table XLV

Age	Females		Males	
	(a)	(b)	(a)	(b)
2	20	2	11	0
3	5	3	11	5
4	6	5	15	6
5	8	8	8	7
14	5	4	9	9
15	4	1	10	10
16	8	6	10	8
17	7	1	16	11
18	10	1	15	10
19	5	0	16	3

TABLE XLVI

Age	Females		Males	
	(a)	(b)	(a)	(b)
13	18	17	9	9
14	5	2	25	23
15	6	0	15	11
16	12	5	10	8
17	10	0	24	7
18	11	0	16	1

girl aged 14 and in a boy aged 16, the majority being at the age of 17 in females and 19 in males. The oldest subjects in whom fusion had not yet appeared were a female aged 18 and a male aged 19 years and 8 months.

DISTAL EPIPHYSIS OF THE TIBIA

This was found to be present in every infant examined including a girl aged 7 months (both sides) and a boy aged 9 months. Borovansky and Hnévkovský found its presence in a boy aged 3 months and 3 weeks.

Table XLVI represents the incidence of occurrence of this epiphysis, columns (a) indicating the number of ankles examined and columns (b) the number of such epiphyses observed at each age group and in each sex respectively.

The youngest girl to show fusion of this epiphysis was aged 13 and the youngest boy 14 years and 9 months. Table XLVI shows that the majority of epiphyses fuse at the age of 14 in girls and 17 in boys. Instances of non-fusion were noted in a female aged 16 years and 4 months and in a male aged 18.

As is the case with the distal epiphysis of the radius and ulna, so are the distal tibial and fibular centers fused approximately simultaneously with the shaft. However, in the girl of 13, quoted above, although the center for the distal end of the tibia had fused, that for the fibula had not yet done so, being thus a violation of the oft-quoted rule that the first epiphyses to appear are the last to unite.

OS MALLEOLI

In a male aged 17 years and 7 months, an ossicle was seen on both sides at the tips of the medial malleoli, and is clearly demonstrable in both the anteroposterior and lateral views. I can nowhere find a record of such an ossicle in the literature. The term os malleoli is suggested.

DISTAL EPIPHYSIS OF FIBULA

This was found present on both sides in a female infant aged 11 months and was likewise found in a boy aged 1 year and 9 months, but was not present in a girl of 9 months nor in a boy aged 1 year and 8 months, although present in all of 7 instances in girls and 3 of 4 boys during their second year.

Table XLVII represents the incidence of occurrence of this epiphysis, columns (a) indicating the number of ankles examined, and (b) the number of epiphyses observed in each age group in each sex respectively.

TABLE XLVII

Age	Females		Males	
	(a)	(b)	(a)	(b)
14	5	2	24	24
15	6	0	15	11
16	12	5	12	10
17	9	0	21	6
18	9	0	14	1

The earliest epiphyses to fuse were found in a girl aged 14 years and 10 months and in a boy aged 15 years and 8 months (both sides). The majority had united in girls at the age of 14 and in boys at 17. Instances of non-fusion were noted in a girl aged 16 years and 4 months and in a boy aged 18.

TARSUS

The calcaneus, talus and in the female only, the cuboid, usually appear before birth. The navicular and the three cuneiforms have not been noted at this period.

Pryor found centers for both calcaneus and talus present in all three premature 8 months babies of both sexes, as well as in

all of 90 other infants of both sexes during the first 9 days after birth.

In my series, no infant was found in whom the centers for the calcaneus, talus or cuboid had not already appeared. The calcaneus usually has an additional epiphysis for the posterior aspect of the heel, known as the apophysis. The other tarsal bones usually ossify from a single center, but sometimes the talus has a separate center for the medial tubercle, which, when it fails to unite with the primary center, forms the os trigonum. In this series, both the navicular and the first cuneiform have been noted arising from two centers.

CENTER FOR CALCANEUS

The calcaneus was first noted in a male fetus of 165 mm. (20 weeks) and in a female of 205 mm. (23 weeks). It was, however, absent in a much larger female fetus of 280 mm. (31½ weeks), although present in 11 of 13 fetuses from 171 to 280 mm. in length (20 to 31½ weeks) as well as in all 12 larger specimens.

Hill reported this center present in 8 of 31 fetuses estimated 16 weeks' gestation.

APOPHYSIS OF CALCANEUS (SEE FIG. 29)

Table XLVIII represents the incidence of occurrence of the apophysis of the calcaneus, columns (a) indicating the number of heels examined and columns (b) the number of instances in which such apophysis has been observed at each age group in each sex respectively.

TABLE XLVIII

Age	Females		Males	
	(a)	(b)	(a)	(b)
7	6	4	8	3
8	4	4	8	5
12	1	0	7	7
13	13	9	8	8
14	4	1	20	18
15	7	0	8	4
16	10	2	16	9
17	7	0	22	2
18	8	0	10	1

FIG. 29. Male, aged thirteen. Note epiphysis at base of fifth metatarsal and apophysis for calcaneus.

The earliest centers to appear were in a girl aged 7 years and 1 month and in a boy aged 7 years and 5 months. Borovansky and Hnévkovský noted the center in a boy aged 6 years and 2 months. The apophysis was absent in a girl aged 7 years and 9 months and in a boy aged 8 years and 7 months, but present in all of 22 instances in children aged 9 to 11 inclusive. It was present in the majority of girls at the age of 7 and of boys aged 8.

The earliest to fuse with the primary center were in a girl aged 12 years and 10 months and in a boy aged 14 years and 6 months. The apophyses were fused in the majority of girls aged 14 and of boys aged 17. The oldest subjects with ununited apophysis were a female aged 16 and a male aged 18.

CENTER FOR TALUS

The center for the talus was seen earliest in a male fetus of 180 mm. (21 weeks) long and in a female of 205 mm. (23 weeks). Its absence was noted in a male of 224 mm. (25 weeks) and in a female of 280 mm. (31½ weeks), the latter being the only instance of 18 fetuses of 233 mm. (26 weeks) or longer.

Hill recorded a center present in a fetus of an estimated age of 16 weeks.

The center for the talus has been found present in all subjects examined after birth.

TABLE XLIX

Age	Females		Males	
	(a)	(b)	(a)	(b)
1	5	5	2	0
2	11	7	11	5
3	9	8	10	9
4	8	6	9	9
5	3	3	10	9

CENTER FOR CUBOID

The center for the cuboid was found in 2 fetuses only, namely a male of 295 mm. (33 weeks) and a female of 315 mm. (36 weeks), but was absent in 6 others of a length of 294 mm. (33 weeks) or more.

Hill recorded this center in a fetus of estimated age of 24 weeks.

A center for this bone was present in every foot in the series examined alive after birth.

Pryor found this bone present in a female 2 days after premature birth at 8 months, but it was absent in another female and in a male, both also prematurely born at 8 months. He also examined 89 infants, 47 females and 42 males, during the first 9 days after birth and found the center present in 31 females and 11 males, that is approximately 66 per cent in girls and 25 per cent in boys. It was, however, found absent in a boy aged 13 days and in a girl aged 25 days.

Menees and Holly found it, however, in 133 females (56.5 per cent) and 92 males (35.0 per cent) when examining 237 females and 263 males within 48 hours after birth. Adair and Scammon found it present in 20 of 45 females and 18 of 55 males within 48 hours after birth.

Hill noted among 35 female and 50 male full time fetuses, 18 and 23 centers respectively.

CENTER FOR TARSAL NAVICULAR

Table XLIX records the incidence of occurrence of this bone, columns (a) representing the number of feet examined, and columns (b) the number of instances in which centers have been observed at each age group in each sex respectively.

The youngest girl with center for the navicular was aged 1 year, the youngest boy 2 years and 6 months. In a girl aged 4 years and 4 months and in a boy aged 5, the center had not yet appeared. The center was present in all 5 instances in girls during their second year and the majority of boys at the age of 3.

In a girl aged 3 years and 4 months, three centers were noted, while in a boy aged 3, two centers were found for this bone.

CENTER FOR FIRST CUNEIFORM

Table L represents the incidence of occurrence of the center for the first cuneiform, columns (a) indicating the number of feet examined, and columns (b) the number of instances in which such centers were found at each age in each sex respectively.

The earliest epiphyses to appear were in a girl aged 2 years (both sides) and in a boy aged 2 years and 6 months. In the girl, it was present on both sides in the first, second and third but not in the fourth and fifth metatarsals, in the boy absent in the four outer metatarsals. In another girl aged 2 years and 7 months, it was also present in the first but absent in all the others. The center was absent in a girl aged 2 years and 4 months and in a boy aged 3 years and 6 months. It was present in the majority of instances in girls at 2 and in boys at the age of 3. Davies and Parsons report the presence of an epiphysis in a female aged 10 months.

TABLE L

Age	Females		Males	
	(a)	(b)	(a)	(b)
2	10	9	9	2
3	6	6	5	4
14	1	0	10	10
15	5	0	5	4
16	7	2	15	11
17	7	0	22	7
18	5	1	11	1

The earliest to fuse were in a girl aged 14 and in a boy aged 15. Although the majority of girls aged 14 showed fusion, it was not until the age of 17 years that this was the case in boys. Instances of non-fusion were found at the age of 18 in both sexes.

EPIPHYSES FOR SECOND, THIRD, FOURTH AND FIFTH METATARSALS

Table LI represents the incidence of occurrence of the epiphyseal centers for the second, third, fourth and fifth metatarsal bones, columns (a) indicating the number of feet examined, and columns (b) the number of centers observed at each age group in each sex respectively.

In a girl aged 2 years, centers were present on both sides for the heads of the second and third metatarsal bones, but had not yet appeared for the fourth and fifth. In a female aged 3 years and 4 months, centers for all five metatarsals were present. In a girl aged 3 years and 5 months, centers were present for the second and third but not for the fourth and fifth. In a boy aged 4, those for the first, second, third and fourth metatarsals were present, but that for the fifth had not yet appeared. In another boy aged 4 years and 6 months, on the right side, centers were present for all five metatarsals, but on the left, although present for the first, second and third, were absent for the fourth and fifth. In a girl aged 2 years and 7 months, and in a boy aged 3 years, although centers were present for the first, epiphyses were absent for all the other metatarsal bones. It is present in at least half of the children of both sexes at the age of 3 for the second and third, and half the girls for the fourth and fifth, and in boys at 4 for the fourth and 5 for the fifth metatarsal.

The youngest subjects in whom the epiphyses were found fused in all four outer metatarsals were a girl aged 14 and a boy aged 15 years and 2 months (both sides).

TABLE LI

Age	Females								Males							
	II		III		IV		V		II		III		IV		V	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
2	10	4	10	4	8	0	8	0	6	0	4	0	3	0	3	0
3	4	4	4	4	4	2	4	2	2	1	2	1	2	0	2	0
4	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	1
14	1	0	1	0	1	0	1	0	9	9	8	8	8	8	8	8
15	7	0	7	0	7	0	7	0	6	4	6	4	6	4	6	4
16	7	1	7	3	7	1	6	1	13	9	14	10	13	9	11	7
17	6	0	5	0	5	0	6	0	18	3	18	3	21	5	21	4
18	5	1	5	1	5	1	5	1	10	0	10	0	9	1	9	1

In a female aged 18 years, centers were present in all five metatarsal bones. They were likewise present in a female aged 17. In a male aged 18, they were absent in the case of the second and third metatarsal bones, although present for the fourth and fifth. Fusion was complete in the majority of girls at the age of 14 and of boys at 17 years of age.

EPIPHYSIS AT BASE OF FIFTH METATARSAL

Sometimes an epiphysis is seen at the base of the fifth metatarsal (see Fig. 29). When this fails to unite with the shaft, it has been described as the os vesalii, which, according to Woollard, has only been recorded 4 times in roentgenograms. Table LII represents the incidence of its occurrence, columns (a) indicating the number of feet examined and columns (b) the number of such centers noted at each age group in each sex respectively.

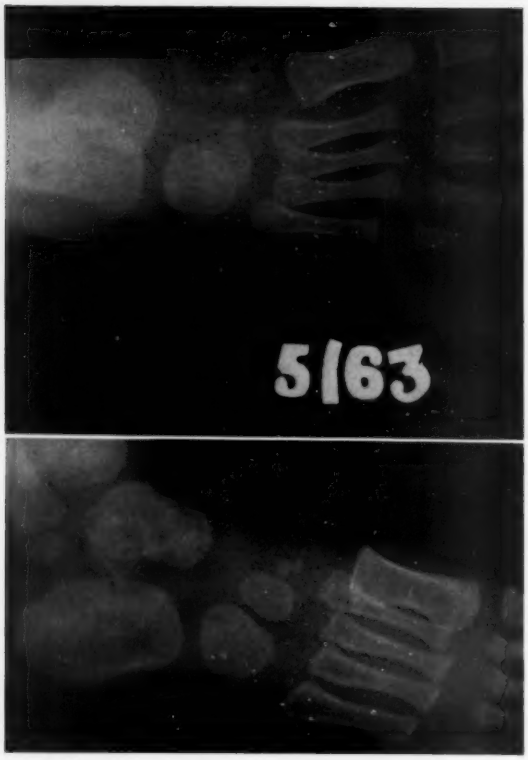

FIG. 30. Female, aged two years three months. Two centers present for first cuneiform.

The youngest female with such an epiphysis was aged 12, the youngest male 13 years and 4 months, but instances were noted at the age of 17 in subjects of unknown sex. Its maximum incidence, in males at least, appears to be at the age of 13 when it was present in 3 of 4 instances. Altogether it occurred 15 times in 100 instances in subjects between the ages of 12 and 17 inclusive. It is evidently not constantly present. Borovansky and Hnévkovský noted a center in a boy aged 11 years and 7 months, but in this series, it was not present in any of 2 instances in girls and 4 in boys aged 11.

TABLE LII

Age	Females		Males	
	(a)	(b)	(a)	(b)
12	3	1	4	0
13	12	2	4	3
14	1	0	15	6
15	5	0	5	0
16	6	0	9	1
17	10	0	19	0

SESAMOID OSSICLES OF HALLUX

There are usually a pair of these beneath the head of the first metatarsal bone on the plantar aspect. The medial sesamoid is frequently split into two by an irregularly transverse fissure taking on the appearance as though fractured. Occasionally the lateral sesamoid is similarly split. These ossicles were found at the age of 9 years and 7 months in a girl and 12 years and 5 months in a boy. Splitting of one of the ossicles on each side was noted in a boy aged 16 years and 4 months. This sesamoid was not present on either side in a girl aged 11 nor in a boy aged 11 years and 2 months, but is noted in all subjects aged 12 years and older.

TABLE LIII

Age	Females		Males	
	(a)	(b)	(a)	(b)
2	9	8	6	1
14	1	0	6	6
15	7	0	5	3
16	6	1	16	11
17	7	2	18	3
18	5	1	9	0

SESAMOID OF SECOND METATARSAL BONE

This was seen upon both sides in a female aged 24 years and 8 months.

SESAMOID OF FIFTH METATARSAL BONE

The only instances of these were seen in females (on both sides in each case) aged 21 years and 2 months and 21 years and 10 months respectively.

PRIMARY CENTERS FOR PROXIMAL ROW OF PHALANGES

In this series every fetus of 62 mm. (11½

weeks) or longer showed the presence of the primary centers for the proximal row of phalanges.

EPIPHYSIS FOR PROXIMAL PHALANX OF HALLUX

Table LIII represents the incidence of the occurrence of the epiphysis at the base of the proximal phalanx of the great toe, columns (a) indicating the number of such toes examined and columns (b) the number of epiphyses observed at each age group in each sex respectively.

The epiphysis at the base of the phalanx was found in a girl aged 2 years (both sides) and in a boy at the age of 2 years and 6 months. In a girl aged 2 years and 4 months it was absent although present in the other phalanges in the row, while it was absent in all five proximal phalanges in a boy aged 2 years and 6 months.

Davies and Parsons record the presence of this epiphysis in a female aged 10 months.

The youngest subjects in whom this epiphysis was found fused were a girl aged 14 and a boy aged 15. Fusion had taken place in the majority of girls at the age of 14 and of boys at 17 years of age. Nonfusion was present in a male aged 17 (although fusion was complete in all the other proximal phalanges) and in a female aged 18.

EPIPHYSES FOR PROXIMAL PHALANGES OF SECOND, THIRD, FOURTH AND FIFTH TOES

Table LIV represents the incidence of occurrence of these epiphyses at the bases of the corresponding proximal phalanges, columns (a) representing the number of feet examined, and columns (b) the number of centers noted at each age group in each sex respectively.

TABLE LIV

Age	Females								Males							
	II		III		IV		V		II		III		IV		V	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	2	2	2	1	2	1	2	0	1	0	0	0	0	0	0	0
2	9	8	9	8	9	8	9	7	6	4	6	4	6	4	6	2
14	1	0	1	0	1	0	1	0	6	4	6	4	7	4	8	2
15	7	0	7	0	6	0	6	0	5	3	5	3	5	3	5	3
16	6	0	6	0	6	0	7	1	14	10	15	10	14	10	15	8
17	6	0	5	0	5	0	5	0	19	4	19	3	19	3	19	4
18	5	1	5	1	6	1	6	1	10	0	9	0	9	0	9	1

The epiphyses at the bases of all the proximal phalanges were found in a girl aged 2 years and in a boy aged 2 years and 6 months. In a girl aged 1 year, it was present in the second, third and fourth but not in the fifth toe. In a boy aged 2 years, the centers for the second, third and fourth were present, but not that for the fifth. In a girl aged 2 years and 7 months and in a boy aged 2 years and 6 months, it had not yet appeared in any of the toes.

The youngest subjects in whom these were found fused with the shafts were a girl aged 14 and a boy 15 years of age. As with the metatarsals, the centers were fused in the majority of girls at the age of 14 and of boys at 17 years of age. In a girl of 18, nonfusion was present in all four digits. This was likewise the case in a boy aged 17. In a male aged 18, although fusion was present in the case of the second, third and fourth toes, that for the little toe was still ununited.

TABLE LV

Age	Females		Males	
	(a)	(b)	(a)	(b)
2	6	4	4	0
3	4	2	2	2
4	1	1	3	2
5	0	0	3	2
6	1	1	1	1
7	1	1	2	0
8	0	0	8	6
9	1	1	4	2
12	2	0	2	2
13	9	6	3	3
14	0	0	6	6
15	6	0	4	1
16	6	0	12	6
17	2	0	15	0
18	2	1	9	0

PRIMARY CENTERS FOR MIDDLE ROW OF PHALANGES

The primary centers for the middle row of phalanges of the toes appear very much later than those of the corresponding phalanges of fingers, which are all present in fetuses of 62 mm. (11½ weeks) or longer. In the foot they appear approximately consecutively in order from the second to the fifth toe. The earliest centers for the second toe were seen in a male of 185 mm. (21 weeks) and in a female of 220 mm. (25 weeks); for the third toe, 171 mm. (20 weeks) in a male and 220 mm. (25 weeks) in a female; fourth toe, 233 mm. (26 weeks) in the female and 275 mm. (31 weeks) in the male; while that for the little toe in the male was noted at 275 mm. (31 weeks). The largest fetuses showing absence of these phalanges in the case of the second toe were 147 mm. (18 weeks) in the male and 165 mm. (20 weeks) in the female; third toe, 150 mm. (18 weeks) in the female and 234 mm. (27 weeks) in the male; fourth toe, 220 mm. (25 weeks) in the female and 234 mm. (27 weeks) in the male; and lastly, for the little toe, a female of 220 mm. (25 weeks) and a male of 234 mm. (27 weeks).

In a boy aged 4 years and 0 months, the primary center for the middle phalanx of the little toe had not yet appeared upon either side.

As the various epiphyses at the bases of the middle row of phalanges develop at different periods, these will be described in separate groups.

EPIPHYSIS AT BASE OF MIDDLE PHALANX OF SECOND TOE

Table LV represents the incidence of occurrence of the epiphyseal center at the base of the middle phalanx of the second toe, columns (a) indicating the number of feet examined and (b) the number of centers observed at each age group and in each sex respectively.

The earliest center was found in a girl aged 2 years and 0 months, in whom it was also present in the third and fourth but not in the fifth. In another girl aged 2 years and 4 months, it was present in all the phalanges of the row. In a boy aged 3 years and 5 months, it was present in the third as well as in the second and in another boy of 3, although present in these two digits, it was absent in the fourth and fifth. It was not present in a girl aged 3 although present in the other phalanges of the row, nor in a boy aged 9 years and 8 months in any of these phalanges on either side. It was present in the majority of girls at the age of 2 and of boys at the age of 3.

The earliest fusion was noted in a girl aged 12 years and 10 months and in a boy aged 15. In a female aged 18 and in a male aged 16 years and 6 months it had not yet fused.

EPIPHYSES AT BASES OF MIDDLE PHALANGES OF THIRD AND FOURTH TOES

Table LVI represents the incidence of occurrence of these epiphyses, columns (a) indicating the number of feet examined and (b) the number of centers observed at each age group in each sex respectively.

These being relatively vestigial digits, the development of their epiphyses is irregular and quite different from the others.

They were both present on both sides in a girl aged 2 years and 0 months. In another girl aged 1 year and 0 months, it was present for the middle toe but not for any other phalanx of the row. In a boy aged 2 years and 0 months, they were present on the right side for the third, fourth and fifth, but not for the second and on the left for the fifth, but not for the second, third and fourth, while in another boy of the same age, it was not present for the third toe on either side, although that for the fourth was present on the right side but not on the left. In a boy aged 5 years and 2 months, they were both present on both sides. They appeared to be present in the majority of females from the age of 2 and of males at the age of 5, but are earlier in the case of the third than in that of the fourth.

In this series, it is impossible to determine the existence of fusion or not, for the non-observance of these epiphyses may be due to one of the three following circumstances: (*a*) stage before appearance of epiphysis, (*b*) non-development of epiphysis and (*c*) fusion of epiphysis with diaphysis. The oldest subjects in whom an epiphysis for the third toe was present was a female aged 18 and a male aged 16 years and 6 months, in whom it was present in the third but not in the fourth toe, and for the fourth toe a girl aged 13 years and 6 months and a boy aged 16. Of 27 and 23 instances respectively in girls aged 5 to 16 inclusive, only 4 epiphyses were present for the third and but 2 for the fourth toe although there were 24 and 14 epiphyses respectively in 48 and 46 instances in boys of the same ages. However, between the ages of 1 to 4 (inclusive) 10 epiphyses were present in 12 instances for the third, and 8 of 13 instances for the fourth, while the corresponding figures for boys were 2 of 8 for the third, and 1 of 9 for the fourth toe.

TABLE LVI

Age	Females				Males			
	III		IV		III		IV	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
1	2	2	2	0	0	0	0	0
2	5	4	6	4	4	1	4	1
3	4	3	4	3	1	1	1	0
4	1	1	1	1	3	0	4	0
5	0	0	0	0	3	2	4	3
6	1	0	1	0	2	2	1	0
7	1	0	1	0	2	0	2	0
8	0	0	0	0	8	6	8	4
9	1	1	0	0	2	1	4	2
10	0	0	0	0	2	1	3	1
11	0	0	1	0	2	2	2	1
12	3	0	2	0	2	2	1	1
13	9	3	8	2	3	1	3	0
14	0	0	0	0	6	3	4	1
15	6	0	4	0	4	1	4	0
16	6	0	6	0	12	3	10	1
17	2	0	3	0	16	0	15	0
18	3	1	4	0	7	0	8	0

EPIPHYSIS AT BASE OF MIDDLE PHALANX OF LITTLE TOE

Of 165 instances, including 55 females and 103 males aged 1 to 18, this epiphysis was found 9 times (5.4 per cent) only. It is

the exception rather than the rule for this epiphysis to be present at any age. The youngest girl with such an epiphysis was aged 2 years and 4 months and the youngest boy 2 years and 0 months (both sides) and the oldest girl was aged 13 years and 6 months (both sides) and the oldest boy 12 years and 1 month.

PRIMARY CENTER FOR DISTAL PHALANX OF HALLUX

Although not present in the female fetus of 62 mm. (11½ weeks), all fetuses measuring 70 mm. (12 weeks) or over showed the center for the proximal phalanx of the hallux.

EPIPHYSIS AT BASE OF DISTAL PHALANX OF HALLUX

Table LVII represents the incidence of occurrence of the epiphysis at the base of the distal phalanx of the hallux, columns (a) indicating the number of big toes examined and columns (b) the number of centers observed at each age group in each sex respectively.

TABLE LVII

Age	Females		Males	
	(a)	(b)	(a)	(b)
13	9	6	3	3
14	0	0	7	7
15	7	0	5	5
16	6	0	12	8
17	4	0	16	0
18	4	1	10	1

An instance of absence of this epiphysis was noted on both sides in a subject (not included in this series) of cleidocraniodysostosis aged 9 years and 8 months.

This epiphysis was present in a girl aged 1 year and 0 months and in a boy aged 1 year and 9 months.

Fusion was present in a girl aged 13 years and 0 months and in a boy aged 15. In the majority of girls aged 15 and of boys aged 17, fusion was complete. Union had not yet occurred on either side in a boy aged 16 years and 6 months, nor was it fused in a girl aged 18.

PRIMARY CENTERS FOR DISTAL PHALANGES OF SECOND, THIRD, FOURTH AND FIFTH TOES

The earliest that the primary centers for the distal phalanges of the second, third, fourth and fifth toes appeared in each case was in a male fetus of 109 mm. (15 weeks). In the case of the little toe, it was present on one side, and in a female fetus of 150 mm. (18 weeks) for the second, third and fourth toes, although absent for the fifth, but was present in all distal digits in a female of 233 mm. (26 weeks) long. In the male fetus of 70 mm. (12 weeks) the whole row was absent, while the distal phalanges for the fourth and fifth toes were not present in a male fetus of 165 mm. (20 weeks), while in a female of 220 mm. (25 weeks) there were not yet any centers for the little toe.

EPIPHYSES AT BASES OF DISTAL PHALANGES OF SECOND, THIRD AND FOURTH TOES

The youngest subject in whom these have appeared in the case of the second and third toes was aged 3 (unknown sex). In a girl aged 3 years and 11 months, those for the third and fourth toes were present. In a boy aged 4 years and 0 months, centers were present on both sides for the fourth although absent on the right side for the third. They were likewise noted in a boy aged 5, while in a girl aged 6 years and 6 months, it was present for the second toe. It was absent in all three digits in a girl aged 3 and a boy aged 8.

Table LVIII shows the incidence of occurrence of these epiphyses, columns (a) indicating the number of feet examined, and columns (b) the number of centers observed at each age group in each sex respectively.

The earliest to fuse were in a girl aged 12 years and 10 months, and in boys aged 15. The majority were fused in girls in the case

Table LVIII

Age	Females						Males					
	II		III		IV		II		III		IV	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
12	2	1	2	1	2	1	1	1	1	1	1	1
13	7	1	7	1	8	5	2	2	2	2	3	3
14	0	0	0	0	0	0	5	5	5	5	4	4
15	4	0	4	0	5	0	3	0	4	1	3	0
16	5	0	6	0	5	0	9	2	9	2	10	2
17	1	0	1	0	3	0	10	0	9	0	10	0
18	4	1	4	1	5	1	7	0	5	0	6	0

of the second and third digits at the age of 13 and in boys aged 15 in all three. Instances of non-fusion were found in a female at 18 and in males at the age of 16.

EPIPHYSIS AT BASE OF DISTAL PHALANX OF LITTLE TOE

Table LIX represents the incidence of occurrence of the epiphysis at the base of the distal phalanx of the fifth toe, columns (a) indicating the number of toes examined and (b) the number of such epiphyses at each age group and in each sex respectively.

The earliest centers to appear in each sex were aged 3. The oldest girl with an epiphysis was aged 13 years and 8 months and the oldest boy 16.

In Table LX the centers given prior to birth represent the earliest periods at which they were observed, while after birth, they indicate the ages at which at least half of the centers and epiphyses have appeared or fused in each sex respectively.

Although the cuboid has been shown as having been found in a male fetus prior to birth, it is also listed among those appearing in males during their first year, when the majority of such centers first make their appearance.

AGES AT WHICH OSSIFICATION CENTERS AND EPIPHYSES APPEAR AND FUSE

Table LXI takes into account only instances noted by the author and the various authorities specified. Columns (a) represent in years and months or years only the age of earliest appearances noted; (b) in years only the age at which at least half of these are noted; (c) age in years and months or years only of oldest subjects in whom these have not yet appeared; (d) age in years and months or years only of earliest age at which fusion has been noted; (e) age in years only at which at least half have fused, and (f) age in years and months or years only of oldest subjects in whom fusion had not yet taken place. Figures in parentheses indicate length of fetuses in millimeters.

OBSTETRIC APPLICATIONS

As the various centers of ossification are rarely clearly recognizable in living intra-

Table LIX

Age	Females		Males	
	(a)	(b)	(a)	(b)
3	2	1	1	1
4	0	0	3	0
5	0	0	3	1
6	0	0	2	1
7	1	1	2	2
8	0	0	6	5
9	0	0	4	2
10	0	0	3	2
11	2	0	3	1
12	1	0	1	0
13	6	1	3	0
14	0	0	4	1
15	4	0	5	0
16	6	0	9	1

TABLE LX

CHRONOLOGICAL ORDER OF APPEARANCE AND FUSION OF OSSIFICATION CENTERS

Before Birth. (Actual observations only.)

30 mm. (9 weeks). Clavicle.

32.5 mm. (49 days after single coitus). Proximal 10 pairs of ribs, primary centers of scapula, humerus, radius, ulna, ilium, femur, tibia and fibula.

62 mm. (11½ weeks). Arches cervical spines, bodies and arches thoracic and lumbar spines, bodies first and second sacral, eleventh pair of ribs, primary centers metacarpals, proximal and distal rows of phalanges of fingers, metatarsals, proximal row of phalanges of toes.

Estimated age 12 weeks. Semicircular canals (Hill).

109 mm. (15 weeks). Bodies lower five cervical and third sacral spines, arch first sacral, middle row of phalanges of fingers, ischium, distal phalanges of second, third, fourth and fifth toes.

134 mm. (17 weeks). Male. Cervical rib.

147 mm. (18 weeks). Arch second sacral.

Male. Body fourth sacral.

150 mm. (18½ weeks). Female. Arch third and fourth sacral. Body fourth sacral.

165 mm. (20 weeks). Bodies atlas, epistropheus.

Female. Body fifth sacral, cervical rib.

Male. Arch third and fourth sacral, pubis, calcaneus, talus.

Estimated age 20 weeks. Hyoid (Hill).

171 mm. (20½ weeks). Male. Arch fifth sacral, middle phalanx third toe.

180 mm. (21 weeks). First, second and third sternebrae. Male. First sacral lateral mass.

185 mm. (21½ weeks). Male. Middle phalanx of second toe.

205 mm. (23 weeks). Female. Arch fifth sacral, pubis, calcaneus, talus.

218 mm. (25 weeks). Fourth sternebra.

220 mm. (25 weeks). Female. First, second and third sacral lateral mass, middle phalanges of second and third toes.

233 mm. (26½ weeks). Female. Middle phalanx of fourth toe.

262 mm. (30 weeks). Distal epiphysis of femur. Female. First segment of coccyx.

275 mm. (31 weeks). Male. Middle phalanx of fourth and fifth toes.

283 mm. (32 weeks). Fifth sternebra.

295 mm. (33 weeks). Sixth sternebra, proximal epiphysis of humerus and tibia. Male. First segment of coccyx and cuboid.

312 mm. (35 weeks). Male. Third sacral lateral mass.

315 mm. (36 weeks). Female. Cuboid.

After Birth.

First year. Capitate, hamate, epiphyses for head of femur, distal tibia and fibula, center for third cuneiform.

Female. Epiphysis greater tubercle humerus, capitulum, distal radius, proximal phalanges of middle, ring and little fingers, distal phalanx of thumb.

Male. Cuboid.

Second year. Epiphyses second and third metacarpals, proximal phalanx of index.

Female. Epiphyses first metacarpal, proximal phalanx of thumb, middle phalanges of middle and ring fingers, distal phalanges of middle and ring fingers, centers tarsal navicular, first and second cuneiforms, epiphyses proximal phalanges of second, third and fourth toes, middle phalanx third toe.

Male. Capitulum, epiphyses distal radius, proximal phalanges of middle, ring and little fingers.

Age 2. Epiphysis fourth metacarpal.

Female. Epiphyses fifth metacarpal, middle phalanges of index and little fingers, centers patella, epiphysis first metatarsal, proximal phalanges of hallux and fifth toes, middle phalanges of second and fourth toes.

Male. Epiphyses greater tubercle of humerus, first metacarpal, distal phalanges of thumb and index, center for first cuneiform, epiphyses for proximal phalanges of second, third and fourth toes.

Age 3. Epiphyses for second and third metatarsals.

Female. Epiphyses distal phalanges index and little fingers, greater trochanter, proximal fibula, distal phalanges of third and fourth toes.

Male. Centers lunate, triquetrum, epiphyses fifth metacarpal, proximal phalanx thumb, middle phalanges middle and ring fingers, centers tarsal navicular and second cuneiform, epiphyses first metatarsal, proximal phalanges hallux and fifth toe, middle phalanx of second toe.

Age 4. Epiphysis fourth metatarsal.

Female. Proximal epiphysis radius, centers carpal navicular, lunate, triquetrum, multangula minus et majus, epiphysis head of fifth tarsal.

Union of greater tubercle with head of humerus.
Male. Epiphyses middle phalanges index and little fingers, distal phalanges middle and ring fingers.
Age 5. Female. Epiphyses medial epicondyle, distal ulna.
Male. Proximal epiphysis radius, centers carpal navicular, multangulum majus, epiphysis distal phalanx little finger, greater trochanter, center patella, epiphyses proximal fibula, head of fifth metatarsal, middle phalanges third and fourth toes, distal phalanges of second, third and fourth toes.
Union of head with greater tubercle of humerus.
Age 6. Female. Epiphysis distal phalanx second toe.
Union epiphyses middle phalanges third and fourth toes.
Male. Distal epiphysis ulna, center multangulum minus.
Age 7. Female. Apophysis of calcaneus.
Male. Medial epicondyle.
Union rami ischium and pubis.
Age 8. Female. Epiphysis olecranon.
Union rami of ischium and pubis.
Male. Apophysis of calcaneus.
Age 9. Female. Epiphysis of trochlea.
Age 10. Female. Center pisiform.
Male. Epiphyses trochlea, olecranon.
Age 11. Female. Epiphysis lateral epicondyle.
Male. Center pisiform.
Age 12. Male. Epiphysis lateral epicondyle, center sesamoid hallux.
Age 13. Centers proximal sesamoids thumb.
Female. Epiphysis angle of coracoid, center sesamoid hallux.
Fusions, angle of coracoid, conjoint distal epiphyses to shaft humerus, distal phalanx thumb, ilium and ischium to pubis, distal phalanges second and third toes.
Male. Fusions middle phalanges third and fourth toes.
Age 14. Female. Epiphyses acromion, iliac crest, lesser trochanter.
Union epiphyses medial epicondyle, olecranon, proximal radius, proximal phalanges middle, ring and little fingers, distal phalanges index, middle and ring fingers, proximal femur, greater trochanter, distal tibia and fibula, apophysis calcaneus, epiphyses all metatarsals, proximal phalanges all toes.
Male. Union distal epiphyses of humerus to each other.
Age 15. Union epiphysis distal phalanx fourth toe.
Female. Centers for sesamoids of index and little fingers.
Union of epiphyses first metacarpal, proximal phalanges thumb and index, distal phalanx little finger, proximal tibia, middle phalanx second, distal phalanx hallux.
Male. Epiphysis for acromion.
Union of ilium and ischium with pubis, distal phalanges second and third toes.
Age 16. Centers for distal sesamoids of thumb.
Female. Epiphysis tuber ischii.
Fusions four inner metacarpals, middle row of phalanges of fingers.
Male. Epiphysis iliac crest.
Fusions distal conjoint epiphysis to shaft of humerus, medial epicondyle, olecranon, proximal radius, distal phalanx middle finger, greater trochanter.
Age 17. Union of epiphysis acromion.
Female. Clavicle.
Union proximal conjoint epiphysis to shaft of humerus, distal ulna, distal femur, proximal fibula.
Male. Fusion epiphyses proximal phalanges thumb, middle row phalanges of fingers, distal phalanges thumb, index, ring and little fingers, proximal femur, distal tibia and fibula, apophysis of calcaneus, epiphyses all metatarsals, proximal row phalanges of toes, middle phalanx second toe, distal phalanx hallux.
Age 18. Female. Union epiphyses clavicle, distal radius.
Male. Center for sesamoid of little finger.
Fusion epiphyses proximal humerus to shaft, all metacarpals, proximal phalanges index, middle, ring and little fingers, proximal tibia.
Age 19. Male. Center for sesamoid of index, epiphysis tuber ischii.
Fusions distal radius, and ulna, femur, proximal fibula.
Age 20. Male. Fusion tuber ischii.
Age 21. Fusion iliac crest.
Female. Fusion tuber ischii.
Male. Epiphysis clavicle.

TABLE LXI

	(a)		(b)		(c)		(d)		(e)		(f)	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Epiphysis clavicle	11 7	11 8	17	21					18		26 11	25
Epiphysis inferior angle scapula	17	16 10			18 11							
Epiphysis base of coracoid process	0 8	5 11			7 6	10 3						
Ditto Menees and Holly												
Epiphysis angle of coracoid	10 2	14 7	13						13		16	19
Epiphysis tip of coracoid		14 7				16						
Epiphysis acromion	12 0	14 11	14	15					17	17	16 1	19 2
Epiphysis head of humerus	(294)	(295)	(315)	(295)								
Ditto Menees and Holly			P.N.	P.N.								
Epiphysis greater tubercle of humerus	0 8	0 6	<1	2	0 11	0 9						
Union greater tubercle head of humerus							3 7		4	5	6	6 6
Union conjoint proximal epiphysis humerus							15 9	16	17	18	20 5	19 2
Epiphysis lateral epicondyle	8 6	10 7	11	12	16	16						
Epiphysis capitulum	0 9	0 11	<1	1		0 8						
Epiphysis trochlea	7	8 9	9	10	16	16						
Fusion ep. lat. epicond., capit., troch.							10	12		14	16	15
Fusion distal conjoint ep. to shaft							13 4	14 7	13	16	16	16
Ditto Sidhom and Derry (Egyptian)										15		
Epiphysis medial epicondyle	2 2	5 5	5	7	6	7 3	10	12	14	16	16	17 0
Ditto Sidhom and Derry (Egyptian)										16		19 3
Ditto Galstaun (Hindu)									14		18	
Epiphysis olecranon	6	7	8	10	10		13 10		14	16	16 0	17 6
Ditto Galstaun (Hindu)											18	
Epiphysis proximal radius	3 4	3 4	4	5	6	8	13 10	14	14	16	19 10	20 5
Ditto Davies and Parsons	2											
Epiphysis distal radius	0 9	1 1	<1	1	1 2	1 7	15 11	17 3	18	19	20 5	23
Ditto Sidhom and Derry (Egyptian)								16		19		
Ditto Galstaun (Hindu)							14	19				
Epiphysis distal ulna	5	5 4	5	6	7	8 6	15 0	17 3	17	19	22	23
Ditto Paterson	4											
Ditto Sidhom and Derry (Egyptian)								15 11		18		
Ditto Galstaun (Hindu)							14					
Ditto Pryor (U.S.A.)									16	19		
Epiphysis styloid process ulna		13 10										
Ditto Borovansky and Hnévkovský (Prague)		5 10										
Center carpal navicular	4 10	4 6	4	5	5 5	8						
Ditto Pryor (U.S.A.)	3 6	4 4	4	7	6 4	8 3						
Center lunate	2 7	1	4	3	3 5	6 11						
Ditto Pryor			3	4	6 3							
Center triquetrum	1 5	2 3	4	3	3	7 3						
Ditto Pryor (U.S.A.)		1 9	2									
Center pisiform	7 2	7	10	11	10 8	14 7						
Center hamate	0 9	0 9	<1	<1		0 2						
Ditto Menees and Holly	2 days	2 days										
Center capitate	0 9	0 2	<1	<1		1 wk.						
Ditto Pryor (U.S.A.)		2 days			0 3	0 7						
Ditto Menees and Holly (U.S.A.)	2 days	2 days										
Center multangulum minus	3 5	3 10	4	6	4	8						
Ditto Pryor (U.S.A.)				7	6 7	8 3						
Center multangulum majus	3 5	5 5	4	5	3 5	8						
Ditto Pryor (U.S.A.)		4 1		7	6 7	8 10						
Epiphysis first metacarpal	1 2	2 6	1	2	2 5	3	13	14	15	18	15	19 7
Ditto Sidhom and Derry (Egyptian)										16		
Ditto Galstaun (Hindu)							14		15			
Epiphysis second metacarpal, distal	1 2	1	1	1	2 5	2	14 9	16	16	18	17	20 7
Ditto Galstaun (Hindu)									14		18	
Epiphysis second metacarpal, base	3	7 11				8 6						
Epiphysis third metacarpal	1 2	1	1	1	2 5	3	14 9	16	16	18	17	19
Ditto Davies and Parsons	1 3											
Ditto Galstaun (Hindu)									14		18	
Epiphysis fourth metacarpal	1 10	1	2	3	2 5	3	14 9	16	16	18	17	19
Ditto Galstaun (Hindu)									14		18	
Epiphysis fifth metacarpal	1 5	1	2	3	2 5	3	14 9	16	16	18	17	19
Ditto Galstaun (Hindu)									14		18	
Epiphyses all metacarpals (Pryor)							14 3					
Epiphysis proximal phalanx thumb	1 11	3 10	1	3	2 5	2 6	13 8	14	15	17	15 6	19 11
Epiphysis proximal phalanx index	1 2	1	1	1		2	13 8	14	15	18	16	19 7
Epiphysis proximal phalanx middle fin.	0 10	1	<1	1		2	13 8	14	14	18	16	19
Epiphysis proximal phalanx ring finger	0 10	1	<1	1		3	14 9	14	14	18	16	19
Epiphysis proximal phalanx little finger	1 2	1	<1	1	1 6	3	13	14	14	18	16	19
Epiphysis middle, ring and little finger (Sidhom and Derry)												19 3
Epiphysis middle phalanx index	1 11	4	2	4	2 5	2	13 8	14	16	17	15 1	19
Epiphysis middle phalanx middle finger	1 11	2 3	1	3	2 5	2	14 9	15 11	18	17	16	19
Epiphysis middle phalanx ring finger	1 11	2 3	2	4	3 5	2 6	14 9	14	16	17	16	19
Epiphysis middle phalanx little finger	1 2	2 3	2	4	3 5	2 6	14 9	14	16	17	15 11	19
Epiphysis distal phalanx thumb	0 10	1	<1	2	1 10	2	13 8	14	13	17	15	19 7
Ditto Sidhom and Derry (Egyptian)										15		
Epiphysis distal phalanx index	3 5	2	3	2	1 11	2	14 9	14	14	17	15	17
Epiphysis distal phalanx middle finger	1 11	4	1	4	1 2	2	14 9	14	14	16	15	17
Epiphysis distal phalanx ring finger	1 11	4	1	4	2 5	2 6	14 9	14	14	17	16	17
Epiphysis distal phalanx little finger	3 5	5	3	5	1 11	2	15 6	14	15	17	15	17
Epiphyses distal phalanges, all fingers (Pryor)							14 3					
Center proximal sesamoid, thumb	9 6	12 8	13	13	12	15						
Center, sesamoid index	11 6	14	15	19	23	27						
Center, sesamoid middle finger	13 10	14 0										
Center, sesamoid ring finger		21										
Center, sesamoid little finger	13 10	14	15	17	23	27						
Center, distal sesamoid thumb	14 9	15	16	16	20	25 2						
Union, centers ilium, ischium and pubis							10 6	13 7	13	15	16 10	17 11

TABLE LXI—*Continued*

	(a)		(b)		(c)		(d)		(e)		(f)	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Union rami of ischium and pubis							3 11	4 0	8	7	11	11 4
Ditto Davies and Parsons								3				
Epiphysis iliac crest	12 0	13 4	14	16	14		17 1		21	21	22 3	22 9
Epiphysis anterior superior iliac spine	13 5				17							
Epiphysis tuber ischii	13 5	13	16	19					21	20	24	21
Proximal epiphysis femur	0 9	0 6	<1	<1	0 2	0 9	13 4	14	14	17	18 2	20 2
Ditto Menees and Holly (U.S.A.)	*	*										
Ditto Davies and Parsons (Britain)	0 6											
Epiphysis greater trochanter	2 7	4 4	3	5	4	6	14 4	15 10	14	16	16 10	17 6
Ditto Borovansky and Hnévkovský (Prague)		3 5										
Epiphysis lesser trochanter	9 0	8 11	14								16 10	17 11
Epiphysis distal femur	(262)	(263)	A.N.	A.N.	(280)	(283)	14	16	17	19	19	19
Ditto Pryor (U.S.A.)						3 days						
Ditto Menees and Holly (U.S.A.)					*	*						
Center for patella	2 6	3 11	2	5	3 0	8						
Ditto Borovansky and Hnévkovský		3 7										
Ditto Hellmer (Sweden)	1 11		4	5								
Center fabella	17	16 5										
Epiphysis proximal tibia	(294)	(294)			(324)	(334)	14	16	15	18	18	19
Ditto Menees and Holly (U.S.A.)			A.N.	A.N.								
Ditto Pryor (U.S.A.)					25 days							
Epiphysis proximal fibula	2 11	3 4	3	5	4	5	14	16	17	19	18	19 8
Epiphysis distal tibia	0 7	0 9	<1	<1			13	14 9	14	17	16 4	18
Ditto Borovansky and Hnévkovský (Prague)		0 3										
Epiphysis distal fibula	0 11	0 9	<1	<1	0 9	1 8	14 10	15	14	17	16 4	18
Center for calcaneus	(165)	(205)	A.N.	A.N.	(280)	(147)						
Apophysis of calcaneus	7 1	7 5	7	8	7 9	8 7	12 10	14 6	14	17	16	18
Ditto Borovansky and Hnévkovský (Prague)		6 2										
Center for talus	(180)	(205)	A.N.	A.N.	(280)	(224)						
Center for cuboid	(315)	(295)										
Ditto Pryor (U.S.A.)			A.N.	<1	25 days	13 days						
Center tarsal navicular	1 0	2 6	1	3	4 4	5						
Center first cuneiform	0 9	2 6	1	2	0 11	2 2						
Center second cuneiform	1 8	2 10	1	3	2 6	2 6						
Center third cuneiform	0 7	0 9	<1	<1	0 9	0 10						
Ditto Menees and Holly (U.S.A.)	*	*										
Epiphysis first metatarsal	2 0	2 6	2	3	2 4	3 6	14	15	14	17	18	18
Ditto Davies and Parsons	0 10											
Epiphysis second metatarsal	2 0	4 6	3	3	2 7	3 6	14	15 2	14	17	18	17
Epiphysis third metatarsal	2 0	4 6	3	3	2 7	3	14	15 2	14	17	18	17
Epiphysis fourth metatarsal	3 4	4 6	4	5	3 5	4 6	14	15 2	14	17	18	18
Epiphysis fifth metatarsal, distal	3 4	4 6	4	5	3 5	4 6	14	15 2	14	17	18	18
Epiphysis fifth metatarsal, base	12	13 4										
Ditto Borovansky and Hnévkovský		11 7										
Epiphysis proximal phalanx hallux	2 0	2 6	2	3	2 4	2 6	14	15	14	17	18	17
Ditto Davies and Parsons (Britain)	0 10											
Epiphysis proximal phalanx second toe	1 0	2 0	1	2	2 7	2 6	14	15	14	17	18	17
Epiphysis proximal phalanx third toe	1 0	2 0	1	2	2 7	2 6	14	15	14	17	18	17
Epiphysis proximal phalanx fourth toe	1 0	2 0	1	2	2 7	2 6	14	15	14	17	18	17
Epiphysis proximal phalanx fifth toe	2 0	2 6	2	3	2 7	2 6	14	15	14	17	18	16 6
Epiphysis middle phalanx second toe	2 0	3 5	2	3	3	9 8	12 10	15	15	17	18	16 6
Epiphysis middle phalanx third toe	1 0	2 0	1	5			6	16	6	13	18	16 6
Epiphysis middle phalanx fourth toe	2 0	2 0	2	5			6	16	6	13	13 6	16
Epiphysis middle phalanx fifth toe	2 4	2 0									13 6	12 1
Epiphysis distal phalanx hallux	1 0	1 9					13 0	15	15	17	18	16 6
Epiphysis distal phalanx second toe	6 6	5	6	5	3	8	12 10	15	13	15	18	16
Epiphysis distal phalanx third toe	3 11	5	3	5	3	8	12 10	15	13	15	18	16
Epiphysis distal phalanx fourth toe	3 11	4 0	3	5	3	8	12 10	15	15	15	18	16
Epiphysis distal phalanx fifth toe	3	3									13 8	16
Sesamoid head of hallux	9 7	12 5	13	12	11	11 2						

A.N. = Antenatal
P.N. = Postnatal
* = Within forty-eight hours after birth

uterine fetuses in roentgenograms taken before the fifth month, the following are significant and should be sought for:

Primary Centers.

Bodies of atlas, epistropheus, fifth sacral and first coccygeal segments.
Arches of third, fourth and fifth sacral vertebrae.
Three segments of lateral mass of sacrum.
Sternebrae.
Pubis.
Calcaneus, talus and cuboid.
Middle row of phalanges of toes.

Epiphyses.

Distal epiphysis of femur.
Proximal epiphysis of tibia.
Epiphysis for head of humerus.

Although apparently not yet recorded as having been encountered in the living intrauterine fetus, it is probable that in rare instances, the capitate, hamate and third

cuneiform may be demonstrated before birth.

If any of the above features can be identified, a study of the text and tables of this article should assist in arriving at an estimate of the period of gestation.

The foregoing tables are based upon actual observations only. The earlier ages at which ossification centers and epiphyses appear and fuse in the female is clearly evident. There are few exceptions, but some of these at least may be due to insufficient material for examination, but as these become more abundant, many apparent discrepancies will disappear and some of the gaps will be filled in at the same time.

In a number of instances, centers of ossification were noted very considerably beyond the range of the mass of those examined, and it is suggested that these might be caused by some abnormality of a pathological nature, perhaps of endocrine origin.

Wherever such have been available, ages have been given in months as well as in years, but where this is not done, the figures cannot be relied upon with the same degree of accuracy.

SUMMARY

1. A comprehensive survey of the time of appearance and fusion of centers of ossification and epiphyses by roentgenological means—as yet the most satisfactory method—has not yet been undertaken.

2. The figures usually given are exceedingly variable and generally incorrect, being frequently based on the methods prevailing before the advent of roentgenology.

3. It is of fundamental importance that an accurate conception of the normal periods of such be available before it is possible to appreciate any departure from the normal, such as might occur in endocrine dysfunction, or other pathological states.

4. Studies of the ossification in the human fetus of varying lengths from 30 mm. up to full time are made, described and tabulated.

5. Studies of the human skeleton in vivo from the date of birth until maturity are also made, described and tabulated.

6. Though some regions, such as the spine, are still incompletely studied, it is believed that this is the first attempt to study individually such bones as those of the hand and foot including the sesamoids. It is quite clear that the metacarpals, metatarsals and phalanges of the hand and foot do not as is usually described develop similarly in each row.

7. Such variations as inconsistency of appearance, asymmetry, irregularities in order of appearance and fusion, difference in the two sexes and in different races, etc., are given.

8. A center for the epiphyses of the symphysis pubis has not been satisfactorily demonstrated, likewise several others commonly accepted. Probably these do not exist.

9. A new undescribed os malleoli has been met with on both sides in one subject. It is believed that the separate center for the lateral mass of a sacralized lumbar vertebra has not been previously described. Cervical ribs have been demonstrated to be present in two fetuses.

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EDITORIALS

POLYOSTOTIC FIBROUS DYSPLASIA

WITHIN a comparatively few years, due to the intensive work of many investigators, fibrous dystrophy involving multiple bones has been differentiated. This differentiation has advanced considerably our knowledge of the diseases of bone which bring about cystic changes. We now know that generalized osteitis fibrosa cystica is definitely a disease associated with hyperparathyroidism and that it presents a distinct clinical entity in contrast to the other forms of localized dystrophy which are unassociated, so far as we know, with any disturbance in the function of the parathyroids.

One of these manifestations is the so-called localized fibrous dystrophy which Lichtenstein[1] believed represents a distinct clinical entity and he proposed the term polyostotic fibrous dysplasia. Since Lichtenstein's original report other cases have appeared in the literature under this designation. Kornblum,[2] and Moehlig and Schreiber,[3] among others, have reported cases of polyostotic fibrous dysplasia and Albright and his coworkers[4] have reported cases quite similar in their manifestations.

Kornblum, in his report, called attention to the fact that in the literature will be found a number of case reports under a variety of titles presenting features essentially the same as those found in polyostotic fibrous dysplasia. The disease apparently is primarily one of childhood but, because of the slowly progressive nature of the disease, the condition is not usually encountered medically until adolescence or adult life. Among Lichtenstein's eight cases the youngest was nineteen and the oldest was forty-seven; the average age of onset of symptoms, however, was ten years. It is a noticeable fact that the condition occurs more frequently in females than in males and the disease is apparently much more common than is generally believed.

The bone lesions, as described by various observers, are always multiple and are thought to be due to some abnormality in development during the fibrous tissue stage of bone development and there is a marked tendency to unilateral involvement of the skeleton. While the lesions are multiple they are not generalized; the bones of the extremities are chiefly involved especially the lower limbs, the femur and tibia being the most frequently affected. While these are the most frequent sites, other portions of the skeleton may be involved, notably the skull, pelvis, ribs and the small bones of the hands and feet.

Attention has been called to the fact that roentgenographically the lesions usually present the rather typical appearance of osteitis fibrosa, namely irregular areas of decreased density, having a ground glass appearance. These areas are often interspersed with bony trabeculae producing a cystic appearance. The changes are only cystic in appearance, however, as on histological study no cysts are found. Increase in the size of the lesions brings about a thinning of the cortex of the bone which may eventually become somewhat expanded and as a result of this the bones become weakened and deformities develop. These deformities are particularly noticeable in the lower extremities and pathologic fractures are not an infrequent occurrence. It has been pointed out that with increasing

[1] Lichtenstein. Cited by Kornblum.

[2] Kornblum, K. Polyostotic fibrous dysplasia. Am. J. Roentgenol. & Rad. Therapy, 1941, *46*, 145–159.

[3] Moehlig, R. C., and Schreiber, F. Polyostotic fibrous dysplasia; report of a case with unilateral involvement. Am. J. Roentgenol. & Rad. Therapy, 1940, *44*, 17–23.

[4] Albright, *et al.* Cited by Kornblum.

age of the patient the lesions show a tendency to retardation in development but never entirely disappear.

Since the bone changes mimic those seen in generalized osteitis fibrosa cystica so strikingly, the blood chemistry and blood calcium and often histopathologic studies are necessary for a definite differentiation of the two conditions.

While the clinical, dermatological and roentgenological aspects of these cases are well established, the etiology of the disease is still a point of considerable discussion. Albright, Scoville and Sulkowitch[5] suggested "that the unilaterality in these cases might best be explained on the basis of a disseminated neurological lesion, to which the endocrine dysfunction is secondary." Moehlig and Schreiber pointed out the hereditary dyspituitarism present on the maternal side in their case and to the presence of hypopituitarism evident in this case. They advanced the opinion that the unilateral involvement of the skeleton is due to an unbalanced chromosomal aberration, in their case the defect being inherited from the maternal side.

A recent report of a typical case of polyostotic fibrous dysplasia with cutaneous pigmentation by Stauffer, *et al.*[6] in which there were present multiple congenital arteriovenous aneurysms in the upper extremity with strong probability of similar communications involving the left femoral artery brings into the discussion the importance of this congenital anomaly as a cause of the bone changes which are observed in this group of cases. These authors further point out the fact that this appears to be the first reported instance of polyostotic fibrous dysplasia with such a complication. The association of congenital vascular anomaly with a disorder of bone likewise a mesodermal derivative strongly suggests that the two may have some congenital factor in common.

The report of these cases lends additional support to the view of Lichtenstein that polyostotic fibrous dysplasia results from a congenital disorder of the bone forming mesenchyme. All cases that come to autopsy with manifest polyostotic fibrous dysplasia in which a thorough examination has been made should be reported in the hope that an accumulation of detailed knowledge regarding these cases may clear up the somewhat obscure etiological factor.

[5] Albright, Scoville and Sulkowitch. Cited by Stauffer, *et al.*

[6] Stauffer, H. M., Arbuckle, R. K., and Aegerter, E. E. Polyostotic fibrous dysplasia with cutaneous pigmentation and congenital arteriovenous aneurysms. *J. Bone & Joint Surg.*, 1941, *23*, 323–334.

FRACTURES IN THE NECK OF THE FEMUR IN CHILDREN

A FRACTURE which involves one of the major epiphyses in children may result in permanent disability of the joint in question. This is particularly true of fractures which involve the femoral neck in children and to a less extent fractures which involve the distal tibial epiphysis.

Quite recently Carrell and Carrell* have called attention to the characteristic site of fractures of the femoral neck in children. This fracture, while relatively infrequent, when it does occur usually involves the cervicotrochanteric junction. This type of fracture usually results from severe trauma. Curiously enough, they state that satisfactory reduction has been more difficult to secure and retain in children sustaining these fractures than in adults by the same commonly employed methods of treatment.

Carrell and Carrell particularly state that one of the complicating features of fractures of the femoral neck in children is the occurrence of an aseptic necrosis, the incidence being much higher in children sustaining this type of fracture than in adults. In

* Carrell, B., and Carrell, W. B. Fractures in the neck of the femur in children with particular reference to aseptic necrosis. *J. Bone & Joint Surg.*, April, 1941, *23*, 225–239.

their recent report of twelve such fractures they point out that aseptic necrosis may occur regardless of the type of treatment but that results in these fractures may be favorably altered by avoiding vigorous manipulation in primary reduction and by a long period of freedom from weight bearing. They found as high as 33.3 per cent of their cases exhibited aseptic necrosis of the capital femoral epiphysis.

This increased tendency to an aseptic necrosis of the femoral head in children is explained by the work of Wolcott who by injection of opaque materials found that the pattern of anastomosis of the vessels in the hips of children up to ten to thirteen years of age differs from that found regularly in about 80 per cent of adult hips. In the adult Wolcott found "that the capsular vessels enter, in two groups of three or four branches each, at the postero-superior and postero-inferior juncture of the cervico-trochanteric region. They may traverse the loose capsular tissue to enter obliquely at the base of the head, and anastomose with the branches from the nutrient and the ligamentum teres vessels. In 20 per cent of adult hips, the ligamentum teres vessel is absent, and in all children it is not patent beyond the fovea until the nucleus for the head is well formed at eleven to thirteen years of age, after which free anastomosis occurs." It is apparently this anatomical difference in the arrangements of the nutrient vessels which accounts for the more marked tendency to aseptic necrosis in childhood.

While fractures of the neck of the femur are of relatively infrequent occurrence, the fact that they do occur and that one of the serious complicating factors is aseptic necrosis of the capital femoral epiphysis should be well understood.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

UNITED STATES OF AMERICA

AMERICAN ROENTGEN RAY SOCIETY
Secretary, Dr. H. Dabney Kerr, University Hospital, Iowa City, Iowa. Annual Meeting: Atlantic City, N. J., Oct. 6–9, 1942.

AMERICAN COLLEGE OF RADIOLOGY
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago, Ill. Annual meeting: Atlantic City, N. J., June 10, 1942.

SECTION ON RADIOLOGY, AMERICAN MEDICAL ASSOCIATION
Secretary, Dr. J. T. Murphy, 421 Michigan St., Toledo, Ohio. Annual meeting: Atlantic City, N. J., June 8–12, 1942.

RADIOLOGICAL SOCIETY OF NORTH AMERICA
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting, 1942: To be announced.

RADIOLOGICAL SECTION, BALTIMORE MEDICAL SOCIETY
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

SECTION ON RADIOLOGY, CALIFORNIA MEDICAL ASSOCIATION
Secretary, Dr. J. D. Coate, 434 Thirtieth St., Oakland, Calif.

RADIOLOGICAL SECTION, CONNECTICUT MEDICAL SOCIETY
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets bi-monthly on second Thursday, at place selected by Secretary. Annual meeting in May.

SECTION ON RADIOLOGY, ILLINOIS STATE MEDICAL SOCIETY
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

RADIOLOGICAL SECTION, LOS ANGELES CO. MED. SOC.
Secretary, Dr. Wilbur Bailey, 2007 Wilshire Blvd., Los Angeles, Calif. Meets on second Wednesday of each month at County Society Building.

RADIOLOGICAL SECTION, SOUTHERN MEDICAL ASSOCIATION
Secretary, Dr. Roy G. Giles, Temple, Texas.

BROOKLYN ROENTGEN RAY SOCIETY
Secretary, Dr. Leo Harrington, 880 Ocean Ave., Brooklyn, N. Y. Meets monthly on fourth Tuesday, October to April.

BUFFALO RADIOLOGICAL SOCIETY
Secretary, Dr. Joseph S. Gian-Francheschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months.

CHICAGO ROENTGEN SOCIETY
Secretary, Dr. C. J. Challenger, 3117 Logan Blvd. Meets second Thursday of each month October to April inclusive at the Palmer House.

CINCINNATI RADIOLOGICAL SOCIETY
Secretary, Dr. J. E. McCarthy, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

CLEVELAND RADIOLOGICAL SOCIETY
Secretary, J. O. Newton, 13921 Terrace Rd., East Cleveland. Meets at 6:30 P.M. at Midday Club on fourth Monday each month, October to April, inclusive.

DENVER RADIOLOGICAL CLUB
Secretary, Dr. Edward J. Meister, 366 Metropolitan Bldg., Denver, Colo. Meets third Friday of each month at Denver Athletic Club.

DETROIT ROENTGEN RAY AND RADIUM SOCIETY
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

FLORIDA STATE RADIOLOGICAL SOCIETY
Secretary, Dr. Walter A. Weed, 204 Exchange Bldg., Orlando, Florida. Meetings in May and November.

GEORGIA RADIOLOGICAL SOCIETY
Secretary, Dr. R. C. Pendergrass, Prather Clinic Bldg., Americus, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

ILLINOIS RADIOLOGICAL SOCIETY
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meets three times a year.

INDIANA ROENTGEN SOCIETY
Secretary, Dr. H. C. Ochsner, Methodist Hospital, Indianapolis. Meeting held the second Sunday in May annually.

KENTUCKY RADIOLOGICAL SOCIETY
Secretary, Dr. W. C. Martin, 321 W. Broadway, Louisville. Meets annually in Louisville on first Saturday in April.

LONG ISLAND RADIOLOGICAL SOCIETY
Secretary, Dr. Marcus Wiener, 1430-48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:30 P.M.

LOUISIANA RADIOLOGICAL SOCIETY
Secretary, Dr. J. R. Anderson, 1130 Louisiana Ave., Shreveport. Meets annually during Louisiana State Medical Society meeting. Next meeting New Orleans, April, 1942.

MICHIGAN ASSOCIATION OF ROENTGENOLOGISTS
Secretary, Dr. E. M. Shebesta, 1429 David Whitney Bldg., Detroit. Three meetings a year, Fall, Winter, Spring.

MILWAUKEE ROENTGEN RAY SOCIETY
Secretary, Dr. I. I. Cowan, Mt. Sinai Hospital, Milwaukee, Wis. Meets monthly on first Friday at University Club.

MINNESOTA RADIOLOGICAL SOCIETY
Secretary, Dr. J. P. Medelman, 572 Lowry Medical Arts Bldg., St. Paul.

NEBRASKA RADIOLOGICAL SOCIETY
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month, at 6 P.M. at either Omaha or Lincoln.

NEW ENGLAND ROENTGEN RAY SOCIETY
Secretary, Dr. Hugh F. Hare, Lahey, Clinic, Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

RADIOLOGICAL SOCIETY OF NEW JERSEY
Secretary, Dr. H. J. Perlberg, 921 Bergen Ave., Jersey City. Meets annually at time and place of State Medical Society. Mid-year meetings at place chosen by president.

NEW YORK ROENTGEN SOCIETY
Secretary, Dr. Paul C. Swenson, Presbyterian Hospital, New York City. Meets monthly on third Monday, New York Academy of Medicine, at 8:00 P.M.

NORTH CAROLINA ROENTGEN RAY SOCIETY
Secretary, Dr. Major Fleming, Rocky Mount, N. C. Annual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

NORTH DAKOTA RADIOLOGICAL SOCIETY
Secretary, Dr. L. A. Nash, St. John's Hospital, Fargo. Meetings held by announcement.

CENTRAL NEW YORK ROENTGEN RAY SOCIETY
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

OHIO RADIOLOGICAL SOCIETY
Secretary, Dr. J. E. McCarthy, 707 Race St., Cincinnati. Meets at time and place of annual meeting of Ohio State Medical Association.

PACIFIC ROENTGEN SOCIETY
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport.

Philadelphia Roentgen Ray Society
Secretary, Dr. B. R. Young, Temple University Hospital. Meeting first Thursday of each month from October to May inclusive at 8:15 P.M., in Thompson Hall, College of Physicians, 19 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. H. W. Jacox, 4800 Friendship Ave. Meets second Wednesday each month, 4:30 P.M., October to June, Pittsburgh Academy of Medicine.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. S. C. Davidson, 277 Alexander St. Meets on second Thursday from October to May, inclusive. 8 P.M., Rochester Academy of Medicine Building.

Rocky Mountain Radiological Society
Secretary, Dr. A. M. Popma, 220 N. First St., Boise, Idaho, Annual meeting in Denver, summer of 1942.

St. Louis Society of Radiologists
Secretary, Dr. W. K. Mueller, University Club Bldg. Meets fourth Wednesday of October, January, March and May, at a place designated by the president.

San Francisco Radiological Society
Secretary, Dr. H. A. Hill, 450 Sutter St., San Francisco. Meets monthly on third Thursday at 7:45 P.M., first six months at Toland Hall, second at Lane Hall.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. F. B. Bogart, 311 Medical Arts Bldg., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. L. W. Baird, Scott and White Clinic, Temple, Texas. Next annual meeting, Houston, Texas, February 7, 1942.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 P.M. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 P.M., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. C. H. Peterson, 603 Medical Arts Bldg., Roanoke, Va. Meets annually in October.

Washington State Radiological Society
Secretary, Dr. K. J. Holtz, American Bank Bldg., Seattle. Meets fourth Monday each month, College Club, Seattle.

X-ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly in evening on third Thursday.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Meets monthly on third Thursday from November to June inclusive, at 8:15 P.M., 32 Welbeck St., London.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month during the winter at 8:15 P.M. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress.
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. A. C. Singleton, Medical Arts Bldg. Toronto, 5, Ontario.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N.S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse Biel. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad, USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 P.M.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

BULLETIN OF THE AMERICAN COLLEGE OF RADIOLOGY

INCLUSIVE HOSPITAL RATES: AN ANALYSIS

When John Jones enters a hospital on the advice of his family doctor, he would like a definite idea of what his hospital bill is going to cost him. He may select a room at a predetermined daily cost according to his tastes and pecuniary status, but no one can tell him how long he will be in the hospital or how many extra charges he will incur before he is discharged. To provide an answer to one or both of these questions, some rather ingenious proposals have been advanced by a number of hospital executives writing in hospital publications during recent years.[1]

An "inclusive" or "flat" rate has been advocated, with enthusiastic claims for its advantages. The basic principle has as many modifications as there are plans in operation. In essence, it amounts to a limited application of the insurance principle. Insurance spreads the cost of a probable or contingent loss over a period of time and over a group of risks. Group hospitalization employs both these factors under plans providing for prepayment by subscribers to cover the cost of future hospitalization by members of the group. Inclusive rates spread the cost of probable expenses over a group, i.e., all patients hospitalized in the institution. It does not spread the cost over a period of time because no payment is made until the expense arises. To the basic rate of the room selected by John Jones is added a fixed or graduated sum to cover the cost of all extras. The patient who does not incur extra expenses helps to pay for the patient who does.

The items included among these "extras" are subject to variation. If the added charge covers nothing more than actual hospital services, the system has much to recommend it. The fact is, however, that almost every one of the writers advocating the system have proposed that, in addition to the many hospital services provided, certain medical services be included in the inclusive rate charges by the hospital. Here we have a fundamental and profound departure from the accepted and approved methods of medical practice. What medical services are to be included? By what arrangement will the hospital charge and collect for the services of physicians? How will the physician be compensated? Can a hospital corporation legally and ethically sell the services of licensed physicians? What would be the ultimate effect of such a development on the status of medical practice?

It is said that some 75 to 90 per cent of the special services of a hospital are customarily included in the fixed room charge. Now, if the room rate is increased to include the remaining 10 to 25 per cent of these special hospital services, the system presents no implications for the practice of medicine. By raising the room charge a specified amount, additional charges for special drugs, sera, special nursing, special dressings, oxygen, transfusions, operating room, delivery room, et cetera, can be eliminated. But the advocates of the system have gone further. Many of them have proposed that the inclusive rate be increased to include the services of a radiologist, a pathologist, an anesthesiologist or other medical specialists. Others have proposed that the fixed hospital charge include complete medical and surgical care.

A fixed inclusive rate to include all possible hospital services may be a wise and sound innovation in hospital accounting procedures. But, when a hospital sets up a limited insurance plan for medical services, it is exceeding its domain and creating serious complications in medical practice. This has all been extensively discussed in connection with group hospitalization plans, and the American Medical Association has, through its House of Delegates, consistently

[1] Altvater, F. V. Hospital rates for 4½ years. *Mod. Hosp.*, 1937, *49*, 47–48.

Altvater, F. V. Theory and application of inclusive or flat rate plans. *Hospitals*, 1940, *14*, 63–65.

Hamilton, J. A. Inclusive rates. *Hospitals*, 1941, *15*, 38–39.

Class, J. V. Stabilizing charges for hospital service through inclusive rates. *Hospitals*, 1941, *15*, 51–52.

Root, V. T. Room and service are important in establishing inclusive rates. *Hosp. Management*, 1941, *51*, 23.

pointed out the dangers of offering medical services as a part of hospital care in hospital insurance schemes. Precisely the same objections are present when medical services are included by the hospital in its fixed charges for hospital care.

Before discussing some of these objections and disadvantages, we should explain in more detail the various applications of the inclusive rate principle. In application, the various modifications of the principle fall within the following types:

1. So-called "middle-rate" plan: This plan was inaugurated under the aegis of the Rosenwald Foundation at the Baker Memorial Hospital in Boston, the institution itself being an experiment in hospital economics.[2] The hospital was built under a gift for the hospitalization of patients of moderate means, between those in the charity wards of Massachusetts General Hospital and the well-to-do in the adjoining Phillips House. Thus the term "middle-rate." Under the plan, the social service department of the hospital sets the complete cost to be borne by each patient admitted, in view of the nature of his condition and his individual circumstances. The fee thus determined includes hospital accommodations, special services, and complete medical or surgical care. Staff physicians participating in the care of the patient are paid from the total sum collected on an agreed fee schedule.

The plan has not been widely copied for obvious reasons. It was introduced under the same sponsorship in Keokuk, Iowa, and abandoned after one year. Except for the fact that a third party determines the doctor's fee, it presents no particular problem in medical practice. Essentially, it entails nothing more than an agreement by staff physicians to treat patients in a designated income bracket at reduced fees, the hospital collecting the fee and turning it over to them. To this extent, it is not an "inclusive" rate plan in the sense we are discussing that system here. It provides an answer to both of the questions discussed above, predetermining the total expense to be incurred regardless of the extent of treatment or length of stay.

2. "Fixed" or "flat" rate plan: Under this plan, a patient's hospital bill is determined by the service on which he is admitted, that is to say, he or she is charged a predetermined flat sum if admitted for tonsillectomy, a different sum for a maternity case, et cetera. The plan has various modifications and has not been widely adopted. Unlike the "middle-rate" plan, the hospital does not determine nor collect fees for the services of physicians. It answers one of the questions referred to, predetermining the hospital bill regardless of the period of hospitalization. Charges for specialists' services for diagnosis and treatment or consultation are extra.

3. "Inclusive-rate" plan: Certain features of this plan may be included in either one of the first two above. Its distinguishing characteristic is in the lumping of all hospital charges into an unitemized "inclusive" rate. Some minor applications of the theory are no doubt employed in all hospitals. But only a few institutions have extended the principle to include certain medical services in the "inclusive" rate for hospitalization, which is the particular point for consideration here.

The general principle is usually applied under one of two basic formulae. In the first, the extras covered by the inclusive rate are added to the basic room rate under a graded plan, highest for the first day and gradually decreasing until the extra charge is eliminated. For example, to a basic room rate of $5.00 there may be added $8.50 for the first day, making a total inclusive rate of $13.50. For the second day, the rate would be $5.00 plus $5.00, or $10.00, and so on until the extra charge is dropped after the seventh or eighth day. The total added charge usually amounts to $20.00 to $35.00.

Under the second formula, a flat extra charge is added to the daily room rate, regardless of the length of stay. For example,

[2] Rorem, C. R. The Middle-Rate Plan for Hospital Patients. Julius Rosenwald Fund Publications, Chicago, 1931.

a $1.00 or $2.00 service charge may be added, making the daily rate for a $5.00 room $6.00 or $7.00.

The patient's hospital bill includes all hospital and medical services with the exception of his attending physician's fee, but it varies according to the number of days in the hospital. Thus the "inclusive rate" plan differs from the "fixed" rate plan.

4. Another adaptation of the essential theory of all these plans is in the so-called "diagnostic rate." A fixed charge is made for "diagnosis" for a twenty-four or forty-eight hour stay in the hospital by ambulatory patients requiring extensive diagnostic procedures. For example, the patient may be admitted on the advance payment of $35.00 or $50.00 and receive, besides room and board for twenty-four hours, roentgen examination, laboratory tests and pathological studies, electrocardiograph, metabolic studies, in fact every special service desired by his attending physician.

There can be no denying that under this system the hospital is competing with private physicians in their own offices. All the special medical medical procedures and consultative services offered in this diagnostic bargain are available in the offices of private physicians. Thus the hospital, a corporation, competes in the practice of medicine with the members of its own staff. This is an unexpected rôle of the hospital which owes its existence to the doctors in the community comprising its staff.

Now, what are some of the disadvantages of a system of inclusive fees which offers medical services in the per diem charge for hospital room?

1. The first disadvantage is so compelling that others may well be superfluous. It is this: a hospital cannot, under the law, engage in the practice of medicine. When it sells the services of physicians, including the charge for these services and collecting therefore in a flat or inclusive rate, it is in fact engaged in the practice of medicine.[3]

[3] Cahal, M. F. The employment of physicians by hospitals: some legal aspects. AM. J. ROENTGENOL. & RAD. THERAPY, 1941, *46*, 271; 416; 560.

2. Patients who clearly understand the theory of the inclusive rate will object to paying for a medical service they do not enjoy. This objection has been minimized by certain writers, but it can hardly be avoided if every patient is told exactly what his increased room rate includes. He knows it includes "extras" and is assured that he would have to pay for them separately otherwise. But, does he know that he is paying for a roentgen consultation, the service of an anesthesiologist, and a specialist in clinical pathology, even though he may not require their attention? If he knows that, will he be entirely pleased if his particular case requires none of these?

As an individual, this writer can answer that question for himself without hesitancy. When his daughter was born in an inclusive rate hospital last year, he objected strenuously to paying $11.00 for an $8.00 room when there was no need for most of the services to which the patient was entitled. Of course, a patient would not object if he received without extra charge a great deal of expensive diagnostic procedures for which the man across the hall was paying. But the man across the hall might object if he were paying the cost of them for somebody else.

3. Medical procedures included in the flat charge will be wastefully used. Experience has indicated that the work of the roentgen department just about doubles under a system by which hospital patients pay for these medical services whether they need them or not. This is to be expected. There is a natural tendency for both the patient and the attending physician to abuse the priviege thus purchased. The radiologist in one flat-rate hospital has made the confidential observation that free roentgen examination had a tendency to supplant diligent use of the stethoscope. Another has said quite frankly that a few attending men on his staff occasionally requested unnecessary roentgen examinations for the simple purpose of impressing their patients.

Is this good economics? Without disput-

ing that the system will result in roentgen consultation in some cases which otherwise would go without it because the patient preferred to avoid the expense, the fact remains that, like so many attractive proposals for eliminating the financial burdens of illness, the disadvantages are likely to outweigh the advantages. It is hard to see how the cost of hospitalized illness can be reduced by making patients pay an increased amount, at least a portion of which is almost certain to go to pay for injudiciousness or downright abuse. How can the per-patient cost of roentgen examination be reduced by doubling it?

4. This inevitable increase in the amount of work performed in the medical departments of radiology and pathology, for instance, is bound to lead to the most egregious evil of all, an adulteration in the quality of professional service rendered. Unless expenses are increased at the same rate as demand—which they will not be—an examination which normally requires thirty minutes of a roentgenologists' time and a half dozen films will be disposed of in ten minutes with a couple of films.

5. Whether or not it is a disadvantage, from the hospital's point of view, one implication of the inclusive rate system should give the medical profession serious pause. We have already discussed the various types of inclusive plans. What is to prevent a hospital which is permitted to establish one plan including medical services from subsequently combining it with another? If it can offer hospital accommodations, plus the services of radiologists, pathologists, cardiologists, physical therapists, and anesthesiologists for a flat rate of $10.00 per day, what is to prevent it from employing an obstetrician on a salary and offering a "middle-rate" plan with complete maternity care for a flat rate of $150.00 or $200.00?[4] It could sell surgery on the same basis. It could employ internists on a salary and render complete medical service at a per diem rate. It could, in short, enter and engage in the practice of medicine through the medium of employed physicians.

A likely result would be price competition between hospitals, consequent reduction in the size and quality of the employed staff, solicitation of patients, and inevitable adulteration in the medical services offered.

6. The only practical way a hospital can include the services of physicians in the rate it charges for its rooms is to employ physicians on a salary, paying their salaries out of the gross income from room charges. We have already shown that this practice raises a question of law. Furthermore, it is contrary to the code of ethics of the medical profession.[5]

Of course, if the medical service is provided on a fee basis, the hospital merely collecting the fee for the doctor as in the "middle-rate" plan, the legal or ethical question is not raised. But if the hospital itself offers the services of consultants or diagnostic specialists in the charge it makes for its rooms, it is exceeding the domain ascribed to it in the care of the sick.

The objections of the radiologist to the inclusive rate proposal are disposed of with refreshing candor by one advocate of the system. He says, "With regard to arrangements with roentgenologists, it can probably be dismissed by saying that, where such rate plans are adopted, an occasional contract may have to be revised in detail insofar as the professional man's remuneration is concerned. But no real difficulty should be encountered if there is a spirit of tolerance, cooperation, and imagination."[6]

Imagination, indeed! It requires little imagination to recognize in this glib state-

[4] Some hospitals are already selling complete "maternity service" and others propose the sale of "tonsillectomies."

[5] ". . . It would seem that in this time of extensive changes in hospital economics the point had arrived at which further marriages between hospitals and staff physicians that make the doctor of medicine the servant of the hospital should be stopped and a series of attempts at divorce among marriages that have already taken place should be instituted. Our accepted ethical principles are adequate at the present time and the cooperation of the Council on Medical Education and Hospitals would be of invaluable assistance. It is not an impossible task, but will need a militant local and national ethical spirit behind it and a frowning on those individuals in the profession who on personal grounds do not object to the gradual subjugation of the medical profession in the growth of hospital domination." Judicial Council of the American Medical Association, *J. Am. M. Ass.*, 1936, *106*, 1197.

[6] *Hospitals*, June, 1941, p. 14.

ment a proposal of profound importance to medicine. Shall the practice of medicine be controlled by hospitals or doctors?

Suppose the hospital-employer finds difficulty in balancing its budget. Will it cut physicians' salaries? Or, will it replace experienced men of recognized ability with younger physicians or men of less competence who are willing to take half the former man's salary? Radiologists and pathologists who have consented to work on a straight salary in a hospital have seen this very thing happen too often to regard it as a remote possibility. For the same room rate, a patient might get a $5,000 or $10,000 surgeon; that would be up to the choice of the hospital. It would determine the quality of medical service it could afford to offer in its bargain rate.

Already a few of the large group hospitalization plans, against the persistent objections of the organized medical profession, have included the services of certain physicians as a part of "hospital care." Suppose the "time" factor is added to the "group" factor and the insurance principle is engrafted upon the "inclusive rate" plan. Suppose then the "inclusive rate" which includes some medical service is combined with the "middle-rate" plan to provide complete medical care. Then we have a lay-managed corporation selling complete medical care on a prepayment basis through the medium of employed physicians.

That this is no idle hypothesis is indicated by a statement by C. R. Rorem in a report on the Boston "middle-rate" plan:

"Any really effective attack will not merely make it easier for the patient to pay his sickness bills after illness occurs, but will enable him to budget for them in advance."[7]

Organized medical societies are rapidly installing plans to permit patients to budget for medical care through prepayment. Hospitals are doing the same for hospital care. They should not, however, either in insurance plans or "inclusive rate" plans, be permitted to sell medical services along with their hospital facilities. It is the responsibility of county medical societies in all communities where attempts are made to extend the functions of the hospital in this manner to point out the inherent dangers by prompt and appropriate action.

MAC F. CAHAL
Secretary

[7] Rorem, C. R. How do Physicians and Patients Like the Middle-Rate Plan for Hospital Care? Julius Rosenwald Fund Publications, Chicago, 1932, p. 13.

CONFERENCE OF MID-WESTERN RADIOLOGISTS

The Sixth Annual Clinical Conference of Mid-Western Radiologists will be held in St. Louis, Missouri, on February 13 and 14, 1942. All meetings will be held at the Chase Hotel. The Conference is sponsored by the St. Louis Society of Radiologists. Further information may be obtained from the Secretary of the St. Louis Society of Radiologists, Dr. W. K. Mueller, University Club Building, St. Louis, Missouri.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers as space permits.

A Text-Book of X-Ray Diagnosis. By British Authors. In three volumes. Volume III. Edited by S. Cochrane Shanks, M.D., M.R.C.P., F.F.R., Honorary Director, X-ray Diagnostic Department, University College Hospital; Radiologist, the Prince of Wales's General Hospital, etc., Peter Kerley, M.D., M.R.C.P., F.F.R., D.M.R.E., Physician to the X-Ray Department, Westminster Hospital; Radiologist, Royal Chest Hospital, etc., and E. W. Twining, M.R.C.S., M.R.C.P., F.F.R., D.M.R.E., Radiologist, Royal Infirmary, Manchester; Radiologist, Christie Hospital; Late Hunterian Professor, Royal College of Surgeons; Lecturer in Radiology, University of Manchester, etc. Cloth. Price £3.3.0. Pp. 800, with 710 illustrations. London: H. K. Lewis & Co., Ltd., 1939.

The previous volumes reviewed on these pages included Volume I on the cardiovascular, respiratory, and genitourinary systems; and Volume II on the alimentary and biliary tracts, the abdomen, the female genital tract and obstetrics.

Volume III, before us, devotes 200 pages to the central nervous system; 50 pages to the accessory nasal sinuses, the labyrinth, and mastoid cells; 430 pages to bones, joints, and soft tissues and the localization of foreign bodies; 60 pages to the teeth and jaws; and 20 pages to the eye. The remainder of the book includes cineradiography and a satisfactory index. The illustrations, of which there are 710 in this volume, are especially good, many of them being elucidated by supplementary line drawings. The text is clear, though relatively brief, concise and well arranged.

This most welcome publication completes the series of three volumes of a textbook on roentgen diagnosis which constitutes by far the most elaborate and best organized presentation of clinical roentgenological diagnosis thus far available to English readers. The editors, authors and publisher have our sincere gratitude.

James T. Case

A Handbook of Radiography. By John A. Ross, M.A. (Camb.), M.R.C.S. (Eng.), L.R.C.P. (Lond.), D.M.R.E. (L'pool), Radiologist, Warrington Infirmary; Visting Radiologist, Borough General Hospital, Warrington; Clinical Assistant, X-Ray Dept. Royal United Hospital, Liverpool; Visiting Radiologist, Newton Memorial Hospital, Lancs. Cloth. Price, 7s. 6d. Pp. 126, with 67 illustrations. London: H. K. Lewis & Co., Ltd., 1940.

This book as described in its title is a handbook or manual of 126 pages for roentgen technicians. Because of its small size, descriptions of technical procedures are necessarily limited. Although intended primarily for technicians, instructions for roentgenoscopy are given in some instances. There are chapters on the care of the patient while in the roentgen department for examination, on the exposure and processing of films, in addition to those describing the methods of examination of the various parts of the body. A chapter is devoted to stereoscopy, tomography, serioscopy, with brief mention of kymography and cineradiography. In the chapter on neuroradiology a small section is devoted to each of the following: ventriculography, encephalography, angiography and myelography. Several methods of localization of foreign bodies are described in detail. Interspersed at frequent intervals are blank pages for written notes. In the appendix are instructions for the preparation of patients for various examinations and a table of factors governing exposure technique. The illustrations are line drawings. No roentgenograms or drawings to illustrate the results obtained in the positions recommended are included. The limitation in size of the book obviously prevented the inclusion of such a valuable feature.

This handbook serves a useful purpose in presenting roentgenographic technique in a brief and concise manner but it will not supplant the more voluminous books on technique which have been published in the past few years.

R. S. Bromer

THE CHOICE OF METHODS OF ROENTGEN EXAMINATION OF THE CHEST FOR DIAGNOSTIC SURVEYS. Medical Series, Bulletin No. 111. By Air Hygiene Foundation of America, Inc. Paper. Pp. 73, with 19 illustrations. Pittsburgh, Pa.: Air Hygiene Foundation of America, Inc., 1940.

This little brochure gives a brief but complete review of all the factors that are involved in making satisfactory roentgenograms of the chest. The first four chapters were written by three physicists of the Moore School of Electrical Engineering, University of Pennsylvania, namely Charles Weyl, S. Reid Warren, Jr., and Dallett B. O'Neill. The fifth chapter was written from the medical point of view by Dr. Eugene P. Pendergrass, Professor of Radiology, University of Pennsylvania.

In the first three chapters is given a discussion of the nature of a roentgenogram, of the roentgen ray, of apparatus for producing roentgen rays and of criteria for the choice of chest roentgenographic techniques. The fourth chapter gives a review of methods for making roentgen surveys of the chest of groups of individuals. The writers have succeeded in presenting fundamental facts concerning the basic physics of roentgen rays, roentgen apparatus and roentgen photography in simple terms which can be understood by the beginner. The most satisfactory roentgenograms of the chest are those made directly on film. For surveys of large groups where expense is important and flat views in only the posteroanterior position can be had, paper roentgenograms may be considered satisfactory. The writers have found that fluorophotoroentgenography on 35 mm. film is inadequate. They are in process of testing 4×5 inch film for this purpose. The importance of interpretation of the roentgenogram by experienced medical roentgenologists is emphasized.

In the last chapter Dr. Pendergrass, from the medical standpoint, reviews requirements for roentgen examination of the chest and discusses methods, positions, procedures, etc.

This bulletin is a valuable source of information for the beginner in roentgenology because basic physics is presented so simply, and for the roentgenologist who is confused by claims for accuracy of the various methods of making roentgen surveys of the chest.

ROSS GOLDEN

PATHOLOGY. By Eugene C. Piette, M.D., Pathologist and Director of the Clinical Laboratories of the West Suburban Hospital, Oak Park, Illinois; formerly Consultant Pathologist, Chicago State Hospital and Assistant Professor of Pathology, College of Medicine, University of Illinois, Chicago, Illinois. Third edition. Cloth. Price, $2.00. Pp. 247, with 60 illustrations. Philadelphia: F. A. Davis Co., 1940.

This small elementary text, now in its third edition, is designed primarily for the instruction of nurses. Like many such works, it may also serve the physician as a quick and profitable means of reviewing principles of pathology, this being in keeping with the present trend to short refresher courses found at our annual meetings.

Containing but 247 pages, including numerous illustrations, the subject matter has been carefully selected to include essentials and omit less important details. However, the book is remarkably comprehensive and deals not only with pathology in the narrower sense of tissue changes and how they are produced, but also with special pathology, clinical pathology, collection of specimens, and autopsies. The material is treated, not as abstract scientific knowledge, but as practical vital facts related to the life and duties of one caring for the sick. The why of various procedures is explained so that instructions written on the chart or given by the physician or instructor are executed intelligently rather than blindly.

The simplicity and clearness with which the book is written makes the reading pleasurable as well as profitable.

E. WALTER HALL

REPORT OF THE TENTH AUSTRALIAN-NEW ZEALAND CANCER CONFERENCE, held at Wellington, New Zealand, 15th to 17th February, 1939. Paper. Pp. 67. Wellington, N. Z.: E. V. Paul, Government Printer, 1939.

This report consists mainly of a series of papers on different phases of the cancer problem as it affects both Australia and New Zealand. Some of the papers deal with the developments of cancer control, with the statistics of cancer as they apply to these two countries, with surgical or radiological methods of treating carcinoma of the rectum, with the improvement and extension of radiologico-physical services, with the

serological diagnosis of cancer, and with the ecology of metastases. But perhaps the most interesting thing to be learned from this report is the degree to which, both in Australia and New Zealand, diagnostic and treatment centers and the associated departments of physics have been established and are controlled by the central and provincial governments. In this direction the impression is gathered that these countries have moved even farther than England itself.

A. U. Desjardins

Graduate Medical Education. Report of the Commission on Graduate Medical Education. Cloth. Pp. 304. Chicago: University of Chicago Press, 1940.

The report published in book form is similar in presentation and context to those published in previous years by the same committee. This report should be read carefully by every physician, but it should be required reading of the executive committee of the medical staff of every hospital and every member of the specialty boards.

There are six chapters which are as follows:

Chapter I Summary.
Chapter II The Interneship.
Chapter III The Residency.
Chapter IV Post Graduate Education.
Chapter V The Specialty Boards.
Chapter VI Post Graduate Education in Great Britain.

One of the important reasons for this report is that the committee is attempting to keep the medical profession informed. They state correctly that "medical practice today is changing rapidly to meet the advances in medical science, the growing desires of the medical profession and the increasing demands of the public." In discussing this problem, the committee have not confined themselves to the medical school but have considered particularly the education of the intern, the training of the resident and the facilities for continual post graduate training of practitioners and specialists.

This committee has a program, the primary object of which is prevention of disease and improvement in medical service to the people. The committee's report is excellent and well worth intensive study.

Eugene P. Pendergrass

DEPARTMENT OF TECHNIQUE

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ROENTGENOGRAPHY OF THE GASTROINTESTINAL TRACT

AN IMPROVEMENT IN THE "SPOT" METHOD

By WALTER W. ROBINSON, M.D.
MEMPHIS, TENNESSEE

TODAY, "spot" roentgenography, introduced by such European investigators as Berg and Chaoul, and developed in this country by Boman, Geyman, Cole, Holmes and Schatzki, Lust, and Bell, has become an integral part of every gastrointestinal examination. In order that satisfactory roentgenograms may be made, four basic principles must be recognized, and incorporated into the apparatus. (1) The equipment must be flexible enough so that *instantaneous* exposures can be made of any part under roentgenoscopic examination. (2) The unit should operate as well in the horizontal as in the vertical position. (3) There should be a *suitable* method of limiting the field of examination and exposure so that the maximum definition of images can be obtained, especially in the roentgenograms. Limiting the field of exposure by adjustment of the roentgenoscopic shutter controls alone does not eliminate the fog of scattered and secondary radiation. (4) Where compression is indicated, it is essential that the device used to secure this should not increase the object-film distance any more than it is necessary (or the fog of superimposed secondary radiation will develop), and that the compression must be positive, and readily instituted and controlled.

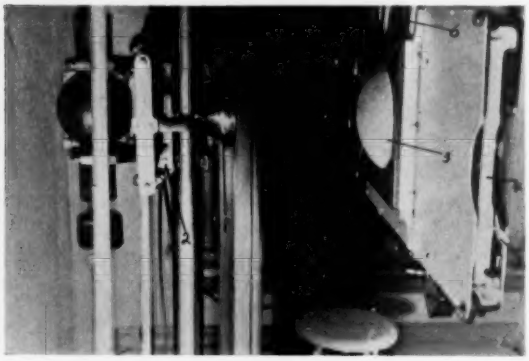

FIG. 1. Left lateral view of "spot" roentgenographic unit in vertical position, showing cone with heavy shoulder (*1*) in special sleeve (*2*) on roentgenoscopic tube carriage, 7 inch compression device (*3*) in position, cassette loaded in leaded tunnel (*4*), and release trigger (*5*) for throwing cassette into position for exposure. The Lysholm grid (*6*) lies directly behind the compression device.

The construction of the proposed unit enables one to make instantaneous exposures of any part under examination in

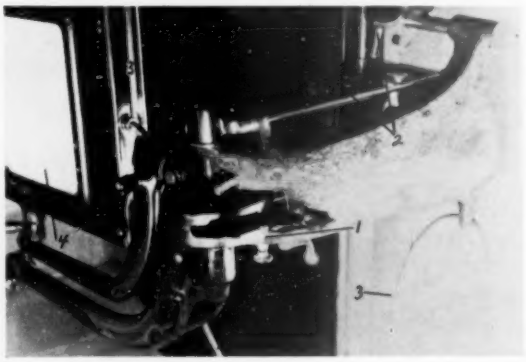

FIG. 2. Right lateral view of "spot" roentgenographic unit in vertical position, showing ratchet lock (*1*) which is closed when compression is desired, tube carriage locks (*2*), cable to auxiliary control switch device (*3*), and fluoroscopic screen (*4*).

either the vertical or horizontal posture by merely releasing the cassette from the leaded tunnel into position behind the fluoroscopic screen, and closing a foot-switch. The low roentgenoscopic current is instantly and automatically changed to the relatively high roentgenographic current by the shifting of the cassette into the exposure position, which action closes the switch to the auxiliary control and actuates a solenoid which shunts the resistance from

Fig. 3. Component parts of "spot" roentgenographic unit: Lysholm grid (*1*), compression device, deflated (*2*), and roentgenoscopic tube cone (*3*).

the Coolidge circuit. The autotransformer is set on that button which will give the desired kilovoltage for the penetration of the part, the auxiliary control switch is opened, and the timer is set for the proper exposure before the roentgenoscopic examination is begun.

By the use of an adequately leaded and specially devised cone of such dimension and shape that its outlet is in close proximity to the under surface of the roentgenoscopic table the portal of entry of the roentgen-ray beam is limited, the field of examination on the fluoroscopic screen is confined to an 8 inch circle or less, and most of the fog of scattered and secondary radiation is eliminated so that all of the roentgenograms contain the maximum in definition which characterizes accepted conventional

Fig. 4. Unit in the horizontal position. Note bar (*1*) which is used to return cassette to original position in leaded tunnel after exposure is made. The Potter-Bucky diaphragm (*2*) under table is shifted out of the field of examination.

roentgenography. Herein lies the heart of our proposal, which distinguishes it strongly from other similar apparatus. This cone is placed in a readily accessible special sleeve built in the base of the roentgenoscopic tube carriage, is easily removed by hand, and occupies the same position in its relation to the tube as the ordinary cone used in orthodox roentgenography. The heavily leaded shoulder which reduces the outlet of the cone is removable, and interchangeable with other shoulders of smaller or larger aperture suitable for the examination of patients of different thickness. Or, a leaded iris diaphragm may be applied over the out-

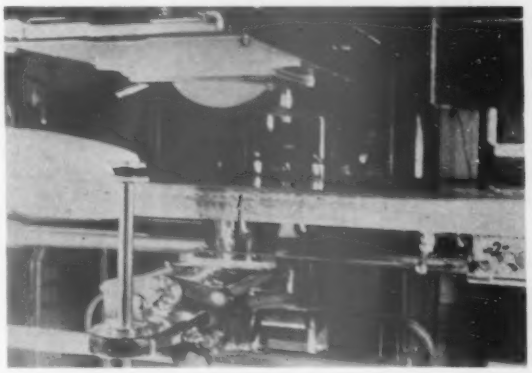

Fig. 5. Enlarged or close-up view of "spot" roentgenographic unit in horizontal position. Note roentgenoscopic tube cone (*1*) underneath surface of table, which may be readily removed by hand when the Potter-Bucky diaphragm (*2*) is used.

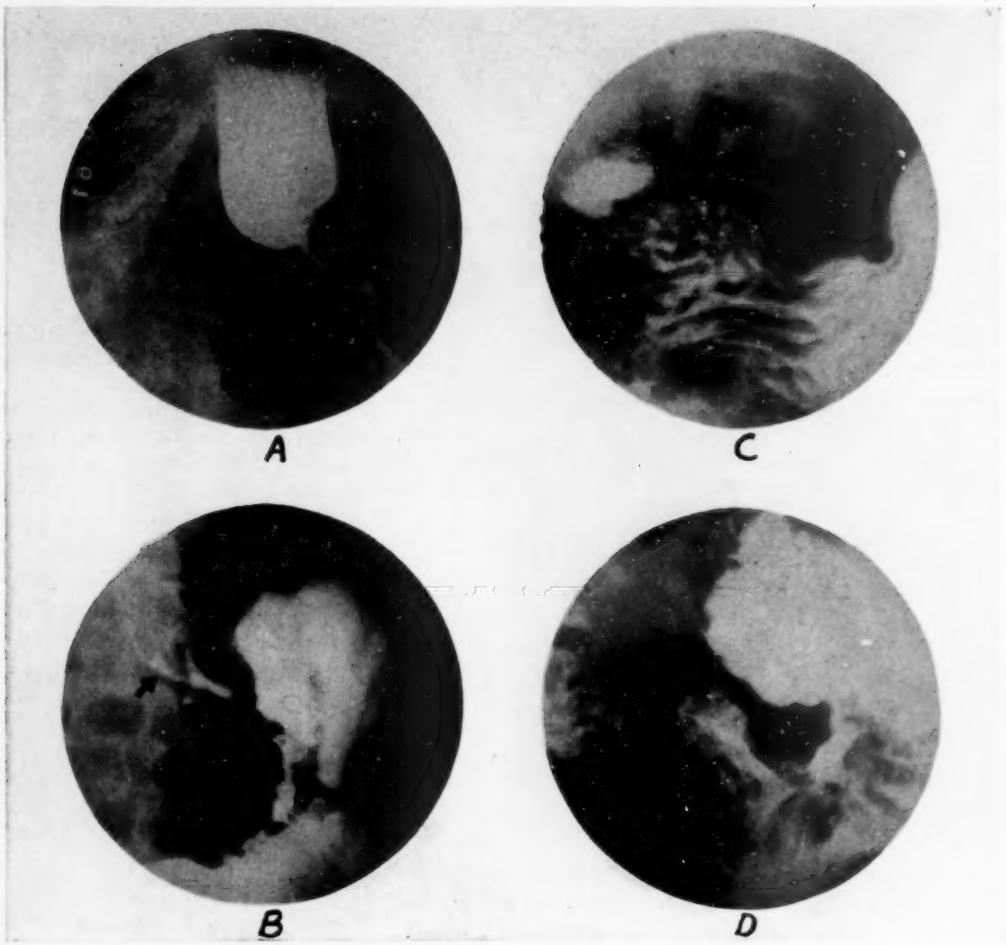

Fig. 6. Reductions of original roentgenograms. *A*, cancer of distal third of esophagus; *B*, cancer of distal third of esophagus, fundus and body of stomach; *C*, study of mucosal pattern of stomach under compression; *D*, deep ulcer of lesser curvature of corpus gastrica under compression, Hampton position.

let of the cone, and the size of the aperture regulated by the use of a lever. This simple device may be added to a "spot" roentgenographic unit of any design, whether single or multiple exposures are projected onto a single film.

About the rear of the roentgenoscopic window of the unit there is a frame which composes two sleeves in parallel in the frontal plane. In the sleeve in juxtaposition to and directly behind the exposure compartment of the cassette tunnel a mounted Lysholm grid is used to absorb any secondary radiation which is not eliminated by the special roentgenoscopic tube cone. However, this is not absolutely essential to the production of satisfactory roentgenograms, and its use is limited to the examination of the heavier patients.

In the sleeve next to the patient is placed an 8 inch, inflated, circular rubber compression bag mounted in a wooden veneer-board frame which is built into a leaded aluminum base in the center of which is a circular 8 inch opening. Depending on the size of the area to be compressed, more or less of the rubber compression bag may be exposed from within the wooden mounting by increasing or reducing the size of the circular opening in the frame, and several compression frames may be constructed to meet the needs of the operator. Ordinarily,

a 7 inch and a 3 inch frame are all that are necessary. At full inflation the anteroposterior thickness of the bag is 1½ inches. For roentgenograms under compression a ratchet lock in the supporting frame of the unit is closed, and any degree of compression may be applied through the inflated bag onto the part under examination. In these roentgenograms there is none of the superimposed secondary radiation produced by the elongated tubular wooden or aluminum compression cones which increase the object-film distance by several inches, nor the disturbing image of a rubber ring such as used in the Chaoul type of rubber compression balloon. The inflated rubber bag flattens as compression is applied. The supportive wooden and aluminum parts of the frame do not cast shadows.

In other words, the unit with all of its component parts, namely, the cassette-loading tunnel with sensitive automatic auxiliary control switch for instantaneous shift-over to roentgenographic current, the specially constructed roentgenoscopic cone, the Lysholm grid and the compression device, is always assembled in readiness for instant use in making "spot" roentgenograms of any part in any position under roentgenoscopic examination.

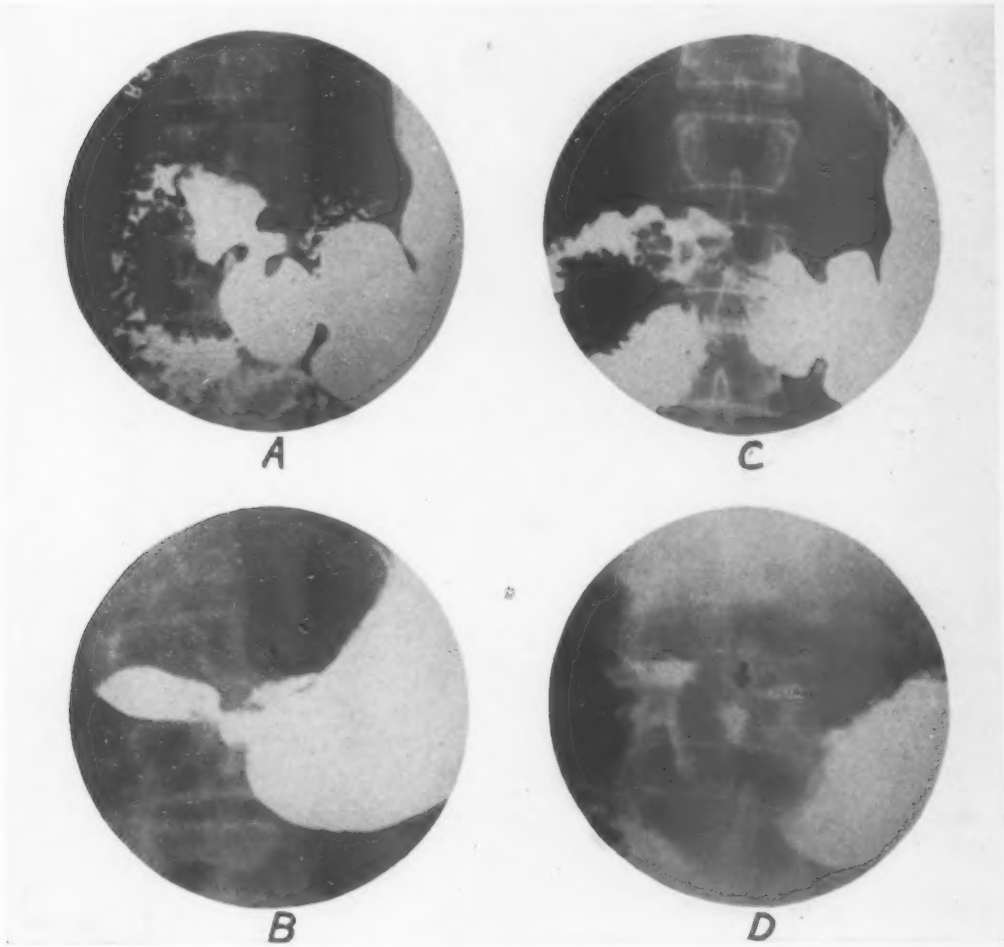

Fig. 7. Reductions of original roentgenograms. *A*, deep pyloric ulcer of lesser curvature of stomach; *B*, large dissecting ulcer crater of the lesser curvature of the corpus gastrica; *C*, deep mucosal ulcer of posterior aspect of cap under compression; *D*, double or centrally placed "kissing" ulcers of the duodenal bulb under compression.

In our work 8″×10″ films are used, and single exposures are made on each film. Exposures may be made in rapid succession by changing cassettes. A single focal spot tube of the line focus type is used, and the exposure time varies from 1/10 to ½ second at 50 to 100 ma. This method of examination has its advantages in that the films may be developed separately, and the roentgenograms may be superimposed to detect any interruption of the peristaltic wave in the stomach as well as to record and positively identify the presence of pylorospasm. Examination in the horizontal plane with the unit permits accurate performance of the Hampton procedure in detecting and roentgenographing bleeding lesions of the pyloric canal and duodenal bulb. Lesions of the small intestine and colon and abnormal positions of the appendix may be readily studied and compression applied where it is needed. The smoothness of the compression is conducive to intelligent study of the mucosal pattern of the stomach and colon. Whereas the barium meal we employ consists of 3½ ounces by weight of dehydrated barium and 7 ounces of water to which is added 1 dram of bicarbonate of soda (a 6

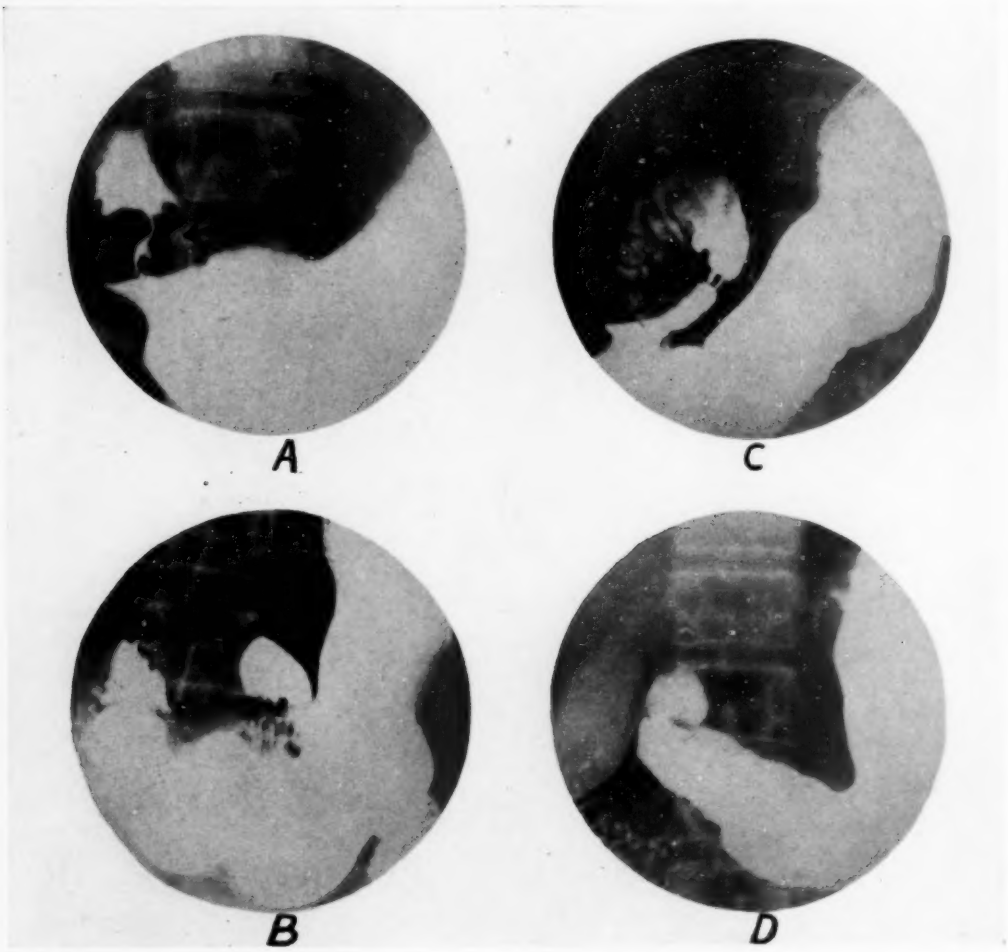

FIG. 8. Reductions of original roentgenograms. *A*, Annular cancer of the pyloric canal; *B*, large diverticulum of the pars ascendens duodeni near ligament of Treitz; *C*, large distended gallbladder producing compression of the pyloric canal and duodenum; *D*, combined barium study—Note dye-filled gallbladder in its relation to the duodenal bulb and pyloric antrum.

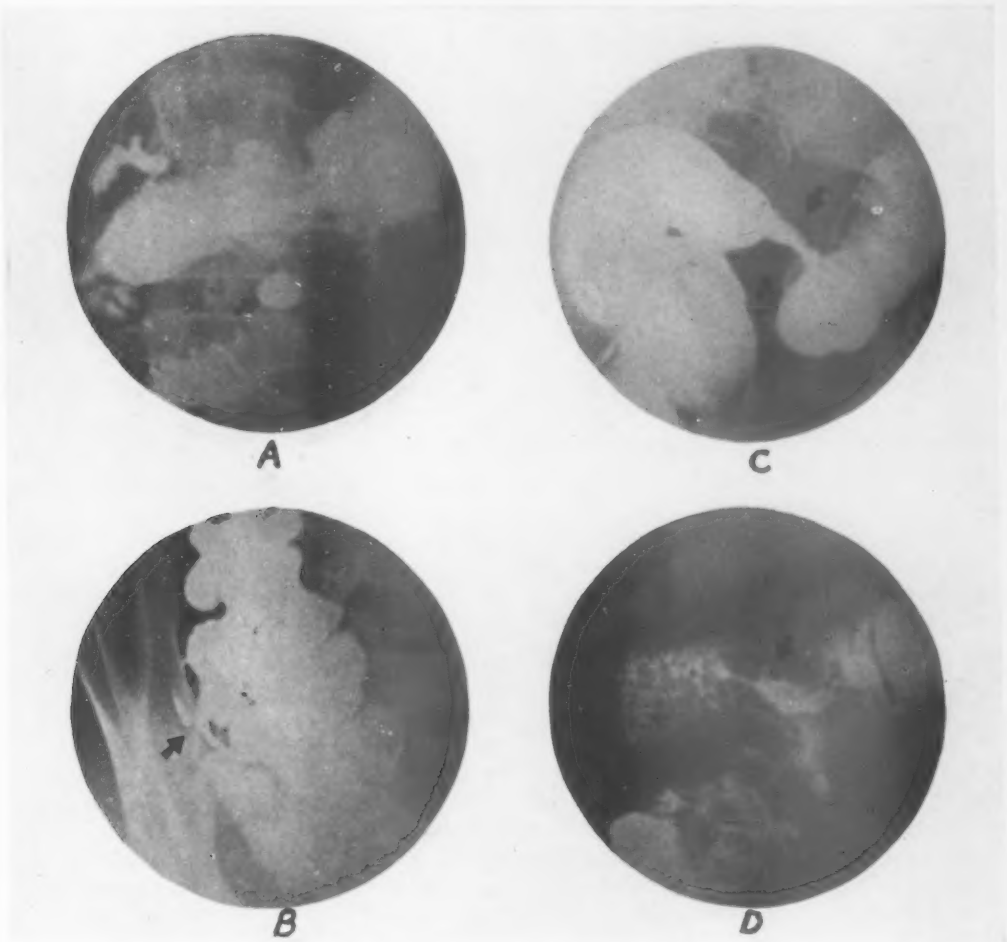

Fig. 9. Reductions of original roentgenograms. *A*, large gastrojejunal ulcer under partial compression; *B*, retrocecal appendix under partial compression; *C*, annular cancer of the sigmoid colon; *D*, cancer of the hepatic flexure of the colon under compression—Note mucosal folds and the coagulated configuration of these in the area of filling defect.

ounce mixture prepared with the mixing machine), if the mucosal pattern is to be studied, $3\frac{1}{2}$ ounces of colloidal aluminum hydroxide is substituted for $3\frac{1}{2}$ ounces of the water. The increased definition during roentgenoscopic examination facilitates satisfactory visualization of the gallbladder in its relation to the duodenum and pyloric antrum by the combined method of study, and the succeeding roentgenograms record all of the images in their entirety.

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ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

HEAD

Glaser, Mark A., and Blaine, Edward S. Fate of cranial defects secondary to fracture and surgery. *Radiology*, June, 1940, *34*, 671–684.

A study of the persistence of fracture lines in the skull is of considerable value in legal medicine. By a careful study of films taken at varying times after the accident it is often possible to determine the approximate age of the fracture.

The authors have made a careful study of 150 cases of skull fracture followed up for some years. Twelve of these cases are described in some detail and roentgenograms given. They found that linear fractures in children less than six years of age disappear in six to twelve months after the accident unless the separation of the fragments has been very wide. In that case absorption of bone may occur and the fracture line may widen instead of disappearing. This may occur in adults also. Linear fractures in adults in the frontal, parietal and temporal regions begin to fade immediately. Complete disappearance rarely occurs, however, under seven months and the average time required for complete disappearance is three to four years. Fractures in the occipital region fade more slowly, sometimes requiring as long as eight years for complete disappearance.

In depressed fractures in which the fragments are not elevated the fragments become rounded and unite and the line of fracture cannot be seen after a certain length of time, though the depression is visible. If bone has been removed by operation or the fragments of a depressed fracture have been removed the defect in the skull never becomes any smaller, the only change being a rounding of the edges.

In one case of depressed fracture the authors turned a bone flap down and hammered the fragment into place. In ten months there was no evidence of the fracture but they think this method too dangerous to be used.

Bone fragments placed in position on operation for depressed fracture must be closely approximated so that all the edges touch in order to secure complete bony union. Otherwise the spaces between the fragments will be visible on roentgen examination.

Osteoperiosteal grafts are the best means of covering skull defects. Whether or not they calcify completely depends on the size of the defect. It requires five to eight years for a defect of average size to become completely calcified.—*Audrey G. Morgan.*

Schillinger, Raphael. An opaque survey of the nasal sinuses. *Radiology*, July, 1940, *35*, 1–16.

The first examinations of the sinuses after the introduction of roentgen methods were chiefly anatomical and related to inflammation, new-growths and various gross pathological changes. This is what the author calls determining the static condition of the sinuses. But it has been found that the dynamic or physiological condition of the sinuses can be determined by roentgen examination also. He describes what he calls an opaque medium survey which is comparable to the modern roentgen diagnostic methods applied to the study of the gallbladder, kidney and gastrointestinal tract.

A control study of the anatomical conditions is made first, the first stage of which determines gross pathology and the second determines the presence of fluid in the antrum; if any is present it is removed. This is followed by the displacement study, the first stage of which determines whether the lumina and openings of the sinuses are patent and the second stage determines the ability of the sinuses to empty. In this study the total sinus system is filled with lipiodol by the displacement method. With normal activity of the cilia the opaque medium will be swept out of the sinuses in twenty-four to forty-eight hours, and if they are not emptied in ninety-six hours it indicates some abnormality in function. Finally a maxillary study is made to determine the capacity of each antrum and its emptying ability. Details of the technique are described and illustrated with roentgenograms.

This is a safe and practical diagnostic method that has no contraindications. It gives information in regard to both the anatomical and functional condition of the sinuses which is of great

value in deciding on surgical procedures. It is possible that secretory disturbances which affect the activity of the cilia is a factor in the production of sinus disease.—*Audrey G. Morgan.*

POSNER, IRVING, and PIATT, ARNOLD D. Ocular hypertelorism with cleft palate and giant-cell tumor. *Radiology*, July, 1940, *35*, 79–81.

Ocular hypertelorism means an abnormally wide distance between the eyes. It is congenital and frequently associated with other deformities such as high palate, syndactylism and undescended testes. But the author does not know of any other cases associated with cleft palate and giant-cell tumor.

His patient was a boy four years of age admitted with the complaint of painful micturition and marked dysuria for a week. There was no blood in the urine but it was dark. No vomiting, chills or fever. The child had been born after a very difficult labor lasting three days. He had harelip and cleft palate which had been corrected surgically. Examination showed a child who seemed to be below par mentally; he did not seem to be acutely ill. His eyes were very prominent and showed rotary nystagmus. His head was box-shaped. The nose showed a moderate deviation of the septum to the right. He remained in the hospital twenty-nine days. All urinalyses were negative.

A preliminary roentgen examination showed a giant-cell tumor of the upper end of the shaft and trochanter of the right femur. There was an incomplete pathologic fracture through the tumor. No evidence of lithiasis.

Roentgen examination of the skull showed the sella turcica about 20 per cent below the average normal. There was a wide spacing between the orbits with the small wings of the sphenoids markedly enlarged. Dentition was imperfect.

The association of cleft palate and abnormal size of the lesser wings of the palate is unusual. There are many cases of cleft palate that show apparently widely separated orbits but roentgen examination shows normal size of the lesser wings. Only ones showing the enlarged lesser wings of the sphenoid as described by Grieg in his original article in 1924 should be called cases of ocular hypertelorism.—*Audrey G. Morgan.*

NECK AND CHEST

SHARPE, CHARLES T. Congenital cystic malformation of the lungs, formerly known as "vesicular" or "hypertrophic pulmonary emphysema," recently described as "congenital cystic disease of the lungs," with report of a case. *Radiology*, June, 1940, *34*, 692–697.

A case is described in a white male, aged twenty. The first indication of the defect was when he started to school and could not run as other boys of his age could. After severe physical effort he would fall and sometimes vomit. He had never had a serious illness. The outstanding findings were barrel-shaped chest, dyspnea and cyanosis on exertion. Roentgen examination showed air cysts of the left lung.

The author calls attention to the fact that these cysts were described clinically long ago and the only new point now is that they can be demonstrated in the living subject by roentgen examination. The patients are short-breathed from infancy and the condition is congenital, evidently due to a primary defect of structure in the lung tissue. The condition was known for centuries as vesicular pulmonary emphysema. Congenital cystic disease of the lungs is a more descriptive name and the author thinks that congenital cystic malformation of the lungs is even better. But in giving descriptions under these names the old name should not be abandoned as otherwise the excellent clinical and pathological descriptions of the older clinicians and pathologists will be lost.—*Audrey G. Morgan.*

KELLEY, CHARLES H. Primary carcinoma of the lung. *Radiology*, July, 1940, *35*, 61–64.

Two cases of primary carcinoma of the lung are described and illustrated with roentgenograms. In both cases the diagnosis was confirmed by bronchoscopy and biopsy. These procedures are necessary in order to confirm the diagnosis and determine the type of cells during life. The roentgen picture is not pathognomonic.

The first patient was a negro porter fifty-five years of age who complained of cough, dyspnea and loss of weight. On March 2, 1938, he was given deep roentgen treatment with 200 kv. (constant potential), 10 ma., skin distance 50 cm., filter 1.0 mm. copper plus 1 mm. aluminum. Five fields 10×15 cm. Cross-fire method. Approximately 9,000 r, measured in air without the scatter factor, was given; rate 200 r at twenty-four hour intervals. The patient had nausea for four or five days. Two weeks later

he was allowed to go home and returned for daily treatments as an out-patient. The tumor decreased in size. He lived for seven months and seventeen days after treatment. Death occurred from metastasis to the liver.

The second patient was a negro cigar-maker fifty years of age. He already had metastasis in the liver on admission and was given only one palliative treatment. He died eighteen days after admission.—*Audrey G. Morgan.*

Hauser, Harry, and Wolpaw, Sidney E. Cavitary bronchogenic carcinoma. *Radiology*, June, 1940, *34*, 698–713.

In some cases of primary carcinoma of the bronchus the symptoms are so much like those of infection that the cancer may be overlooked. This is especially true in cases with cavity formation for they may closely resemble lung abscess and tuberculosis. As surgery may be effective in early cancer of the lung, particularly of the squamous cell type, in which cavitation is most frequent, it is important to make the differentiation.

In cases in which roentgen examination shows cavities there are certain signs that suggest cancer, such as insidious onset, nonproductive cough, persistent pain, decreased breath sounds and bronchographic evidence of constriction of the bronchus. All available means of differential diagnosis should be utilized, particularly bronchoscopic examination, especially in patients more than forty years of age.

The authors studied 127 cases of primary bronchogenic carcinoma admitted to the Cleveland City Hospital from 1927 to 1937 and found cavities in fifteen of them (12 per cent). Nine of these cases are described and illustrated with roentgenograms.—*Audrey G. Morgan.*

ABDOMEN

Chont, L. K. Primary sarcoma of the stomach. *Radiology*, June, 1940, *34*, 714–720.

Sarcoma of the stomach is rare but doubtless many cases are not recognized because of the lack of characteristic clinical and roentgen signs. Sarcomas constitute about 1 per cent of malignant tumors of the stomach. The age range is greater than that of carcinoma. Cases have been described in every decade of life up to the ninth. The general health is less affected than in carcinoma. The general symptoms of cancer—indigestion, hemorrhage and vomiting, occur later than in carcinoma because the mucosa is only secondarily involved. They are more apt to appear on the greater curvature while carcinomas are more apt to appear on the lesser curvature.

Well-defined endogastric and exogastric sarcomas should be treated surgically followed by roentgen irradiation. The infiltrative types and inoperable cases should be treated by irradiation. Great care must be used in roentgen treatment because these tumors are very radiosensitive. Rapid absorption of the tumor may cause toxicosis and even death or a gastric artery may be perforated, causing hemorrhage and death. The area to be treated should be divided into small fields and small daily and total doses given.

Three cases are described and illustrated with roentgenograms. The first patient had typical symptoms of peptic ulcer with a pain-food-ease rhythm that had persisted for nine months, without nausea or vomiting. She was sixty-one years old. She had a large endogastric tumor with deeply indented relief, indicating destruction of the mucous membrane, which had resulted in occult bleeding, anacidity and anemia.

The second patient, a man of sixty-five, had fairly typical ulcer symptoms of nine months' duration with nausea and vomiting during the last month. As the tumor was exogastric the mucosa was not injured and therefore the blood picture was normal, acidity only slightly lowered and there were only traces of occult bleeding.

The patient in the third case was a boy three and a half years of age, one of the youngest on record. A diagnosis of sarcoma was made on roentgen examination but the decision in favor of sarcoma instead of carcinoma was based largely on the patient's age. As there was a history of unusually frequent vomiting, indigestion starting soon after birth, constant stomach symptoms and disseminated metastasis at the age of three and a half years, the author believes this is a case of congenital, infiltrating lymphosarcoma.—*Audrey G. Morgan.*

Ryan, Eric J. Duodenal ulcer in the presence of a gall-bladder symptomatology. *Radiology*, June, 1940, *34*, 685–690.

The author describes 2 cases in which patients came to him with symptoms of cholecystitis. Physical examination indicated gallbladder disease. On operation ulcers of the duodenum were found. There were adhesions of the gallbladder in both cases and an appearance that suggested chronic cholecystitis. In one

there were gallstones. He thinks that in these cases the primary pathological condition was in the duodenum and that the inflammation extended to the gallbladder and on examination the symptoms of the secondary condition overshadowed those of the primary condition. In cases with some of the symptoms of peptic ulcer and symptoms of gallbladder disease the patient should not only be examined for lesions of the gallbladder but should also be given a complete gastrointestinal examination.

In the discussion Dr. Newcomer said that he had shown in published papers that any change in the intimate relation of the antrum and cap to the gallbladder interferes with the normal function of the latter organ. Therefore a duodenal ulcer with peritonitis or adhesions will sooner or later cause stagnation in the gallbladder and cholecystitis. He does not believe that the pathological condition in the gallbladder is caused by direct extension of the infection from the antrum.

Dr. Rhinehart said that it is not necessary to tell roentgenologists that complete examination of all the hollow abdominal viscera must be made in order to establish a diagnosis.

Dr. Feldman said that he believed dyskinesia of the gallbladder is caused by its close proximity to the duodenum, causing associated symptoms as a result of adhesions between the two organs or excessive irritability.

Dr. Ryan said in closing that in cases with indefinite findings of this type as complete an examination as possible should be insisted on.—*Audrey G. Morgan.*

KOPSTEIN, GEZA G. A roentgenologic contribution to the physiology and anatomy of intestinal motility. *Radiology*, July, 1940, *35*, 39–44.

The author reports a study of intestinal motility in 100 young male medical students and 12 women office workers all apparently in the best of health and with normal bowel movements. In two groups of individuals 60 to 70 grams barium sulphate in water suspension was given in the morning. Roentgenograms were taken at three, eight and twenty-four hours until the digestive tract was empty. In the two groups the emptying of the cecum occurred in twenty-four hours in 92.06 per cent and 88.09 per cent respectively. In from 7.92 to 11.9 per cent of the control tests the emptying time was within forty-eight hours. There was not a single normal individual in whom the emptying time of the cecum was more than forty-eight hours. Therefore a cecal emptying time of seventy-two hours is a sign of pathologically delayed motility.

Small residues, either in the form of spots or more extended but thin layers, do not show retention. Retention means not only a delayed propulsion of the colon contents but changes affecting both the section of the colon in question and the motor function of the whole colon. There are considerable variations in cecal emptying time in the same individual on different tests. A comparatively slow cecal emptying time does not necessarily cause a delay in total emptying time.

The variations in the colon shown by anatomical studies, such as high or low cecum, cecum mobile, low position of the transverse colon, redundancy of the sigmoid colon, which is congenital, etc., do not affect emptying time. A mere low position of the transverse colon does not constitute ptosis. Coloptosis means not merely downward displacement of the transverse colon but also of the flexures, so that the whole colon is lowered. Sometimes when such anomalies are found they are attributed to disease and this study is useful as showing that they may exist in perfectly normal persons.—*Audrey G. Morgan.*

SCHATZKI, RICHARD. The roentgenologic differential diagnosis between cancer and diverticulitis of the colon. *Radiology*, June, 1940, *34*, 651–662.

Cases are described which illustrate the difficulty of differentiating between cancer and diverticulitis on operation. Besides preoperative diagnosis is important because operation is rarely indicated in diverticulitis and operative mortality is high. Differentiation often cannot be made from the clinical symptoms. Blood in the stools indicates cancer and if it is present in diverticulitis a search should be made for some other source of the bleeding.

The responsibility for this differentiation therefore rests almost entirely on the roentgenologist. The roentgen differentiation is easy in many cases, difficult in some and almost impossible in a few. Often the increased inflammatory swelling in diverticulitis results in a bizarre fringed outline giving such a characteristic deformity that it cannot be confused with cancer. But diagnosis is difficult when the in-

flammatory masses are evenly arranged throughout the wall producing a concentric constriction with cone-shaped ends very similar to that of cancer. A case is described that simulated cancer very closely as the constricted area was not coneshaped but had a shelf-like margin on both ends which is usually considered pathognomonic of cancer. In some of these cases the preservation of the mucosal folds is the only finding that differentiates diverticulitis from cancer. Cancer may occasionally produce a slightly fold-like picture but these folds can ordinarily be distinguished from normal ones. But a warning is given against indiscriminate interpretation of the folds, particularly when they are the only differential sign. Sometimes the two diseases coexist so that the presence of diverticulosis or diverticulitis proximal or distal to the constricted area does not exclude cancer. Diverticula can almost always be demonstrated in diverticulitis.

In the discussion Dr. Case said that the demonstration of mucosal folds is a valuable means of differentiation but that if air is introduced into the colon for this purpose it should be done with great care. He showed slides of a number of cases and discussed the differentiation. He emphasized the importance of making films of the sigmoid in the oblique projection and, if diverticula were suspected, of making delayed films in order to give the opaque medium time to enter the diverticula.

Dr. Feldman called attention to the fact that diverticulitis and carcinoma may coexist. He thinks the mucosal relief film is the most important means of differentiation. In diverticulitis the obstruction is rarely complete and there is rarely bleeding unless there is some complication such as ulcer or polyps.

Dr. Schatzki in closing said that the shelf-like appearance described in one of his cases was much more frequent in cancer than in diverticulitis and if it were present on both sides of a lesion he would hesitate very much in deciding against cancer unless there were other decisive signs. The presence of diverticula does not help much in differential diagnosis but their absence does and therefore it is important, but often difficult, to prove their absence. Their presence may be important if they are in the constricted area because they rarely, if ever, occur in a cancerous constriction.—*Audrey G. Morgan.*

ROENTGEN AND RADIUM THERAPY

Wigby, Palmer E., and Cohen, Meyer. Radiation therapy of carcinoma of the skin. *Radiology*, July, 1940, *35*, 70–78.

The authors analyze the cases of carcinoma of the skin treated in the Parkland Hospital in Dallas, Texas, for the past two years; 83 lesions were treated in 70 patients. The proper treatment of cancer of the skin is extremely important as there are about 4,000 deaths every year in the United States from this disease. At least 85 per cent of all skin carcinomas are curable and of the curable cases 95 per cent can be cured with irradiation alone. In addition to giving tables showing the treatment and results in their own cases the authors review the literature of the subject with the object of determining the optimum technique for curing the largest number of cases by the first series of treatments.

They conclude that in basal cell carcinoma of the skin at least 4,000 r and preferably 5,000 r should be given of low voltage roentgen therapy, 90 to 130 kv. (peak), using a combination of no filtration and 1 mm. aluminum filtration at the first treatment or during the first series of treatments. Intradermal, adenocystic, infiltrating basal cell and squamous cell tumors should be given between 5,500 and 6,500 r, using medium and high voltage roentgen rays and from 0.5 mm. aluminum to 2 mm. copper filtration and giving about 200 r daily. Small lesions may be given larger daily doses—1,000 r the first day and 600 r per day after that.

Temporizing treatment is a mistake for in the majority of cases treated in this way a simple treatment problem is converted into a long drawn out and difficult one which may result in the death of the patient.—*Audrey G. Morgan.*

Rosh, Rieva. Factors influencing the prognosis in the treatment of carcinoma of the cervix. *Radiology*, July, 1940, *35*, 17–22.

This article is based on 795 cases of carcinoma of the cervix seen at Bellevue Hospital between 1925 and 1937. In 261 of the cases the disease was so far advanced that the patients had to be sent to the City Cancer Institute for custodial care and 182 of them died shortly afterward. Of the remaining 534 who were treated at Bellevue 394 had involvement of the parametrium. Of the whole number 145 are now

alive and well and have been examined recently.

The stage of the disease of course plays a prominent part in the prognosis. If proper treatment is used a good prognosis may be given with reasonable assurance in Stages I and II. In Stage III the prognosis should be guarded as the grading will depend to a great extent on the experience and interpretation of the examiner. Some cases that have just passed beyond the border of Stage II will give good results while others at the borderline of Stage IV may not respond at all. The progress from stage to stage varies in different cases. It may progress from Stage I to Stage IV within six months. The classification used was that adopted by the League of Nations.

There is no absolute method of determining which cases are radioresistant and which ones are sensitive to irradiation. Some cases classed as radioresistant have given excellent results while failure resulted in others of the so-called radiosensitive type.

None of the cases that were really in Stage IV have survived the five year period. Some of the cases that were diagnosed clinically as Stage IV were not really as far advanced as they were thought to be on the first examination, as associated infection had interfered with the proper interpretation of the case. It is impossible to separate some of these cases from the hopeless ones and make a definite prognosis until the infection has been cleared up. If it is at all possible treatment may be attempted in cases that seem to be hopeless from the clinical point of view and occasionally it is successful in such cases. Success in all cases of course is influenced not only by the stage of the disease but also by the general condition of the patient, the quality of the radiation used, the continuity of the treatment and individual susceptibility, also by complications that may develop.—*Audrey G. Morgan.*

O'BRIEN, FREDERICK W. Radiation of cancer of the cervix. *Radiology*, July, 1940, *35*, 23–27.

This paper is based on 262 cases treated at the Boston City Hospital. The classification is based on that of the League of Nations in which Stages I, II, III and IV mean practically early, borderline, advanced and palliative cases. Of the whole number 20.2 per cent were in Stage I, 14.5 per cent in Stage II, 31 per cent in Stage III and 34.3 per cent in Stage IV. The large percentage of Stage IV patients is probably due to the low economic status of the patients admitted to a large municipal hospital. Of the Stage I patients 42.8 per cent have survived the five year period, of the Stage II patients 33.3 per cent, of the Stage III patients 33.3 per cent and of the Stage IV patients 8.3 per cent. All of the patients who survived for five years had repeated irradiation. The maximum dose of radium that can be used safely is about 3,500 mg-hr. for a single continuous application in the cervical canal.

There is no proof that the end-result is better when 30 mg. is used intracervically for 100 hours than when 100 mg. is used for thirty hours. But there is convincing histopathologic evidence that the biologic effect is directly related to the distribution of the radium. It should be distributed diffusely, not massed in one place.

The greatest need is to increase the irradiation in the parametrium. This can be accomplished in early cases by the use of the colpostat.

A survey of this group of cases shows that the result depends on the stage of the disease rather than on the histological type of the tumor. This was confirmed by Chambers, pathologist to the Marie Curie Hospital. She examined 500 cases and found that there was little difference in the response of the different histological types. None of the histological types showed a difference of more than 15 per cent in either local cure or the number of three year survivals.—*Audrey G. Morgan.*

FRIEDMAN, MILTON. The treatment of carcinoma of the corpus uteri. *Radiology*, July, 1940, *35*, 28–38.

The author describes a new radium applicator which he calls a hysterostat. It is illustrated and roentgenograms given showing its position in the uterus. It consists of a crosspiece and two to four lateral tandem inserters, and can be fitted to uterine cavities of various sizes and shapes. Stainless steel tubes for the radium tubes are attached to the ends of the crosspiece and the lateral tandems. With a primary filter of 1.5 mm. platinum and a secondary filter of 0.4 mm. steel a dose of 1,000 mg-hr. per tube can be given. Total doses of 4,000 to 7,660 mg-hr. have been given.

In the past two years 13 patients with carcinoma of the body of the uterus have been treated with this instrument. In 8 of the cases total hysterectomy was performed within four

to six weeks after the radium treatment. In 7 of these cases the uteri showed no residual cancer.

This paper was followed by a discussion of the three papers on cancer of the uterus (see two above abstracts). Dr. Fricke said that the primary factor that influences the prognosis in the treatment of carcinoma of the cervix is the stage of the disease. Other factors are the gross aspect of the lesion, the age of the patient, other diseases associated with the cancer, adequate treatment carefully planned, and cooperation of the patient in returning regularly for re-examination. He agrees that the microscopic picture is not a factor in prognosis but believes it should be continued as much may be learned from it.

Dr. Kaplan said it is harder to control cancer in the younger age group because the cancer cells grow more rapidly in the young. Most patients in municipal hospitals are of the indigent type and the care and follow-up of these patients is particularly difficult. Unlike Dr. O'Brien he gives a roentgen treatment first, then radium and then roentgen radiation again. He believes the use of a small amount of radium over a long period gives the best results. He uses roentgen radiation first because he believes it reduces infection, controls bleeding and reaches areas of the tumor not reached by radium. Large amounts of radium do not reach the outlying parts of the tumor but cause increased local necrosis. He has had good results by using the colpostat with a heavier filter and a larger dose than some physicians use. He does not think that the large doses given have had worse effects than the smaller doses given elsewhere. He believes, as does Regaud, that one intense treatment should be used for cancer of the cervix. Repeated treatment does not control it as well.

Associated infection causes a great deal of trouble, usually with ordinary pus cocci. There is also a great deal of difficulty with syphilitic cases. They have had few cases of tuberculosis associated with cancer of the cervix. Sometimes radium is blamed for blocking of the ureters that has really been caused by infection. He thinks the hysterostat described by Dr. Friedman valuable. In inoperable cases or ones in which operation is refused this radium method plus additional roentgen irradiation through the pelvis, plus additional roentgen irradiation in the vagina will often prolong the life of a patient with cancer that is otherwise hopeless.

Dr. Healy said that any method of treatment that delivers less than three erythema doses to a point 5 cm. laterally from the cervix will fail to control the disease in the majority of patients. It is very important to be able to crossfire the parametrium without cross-firing the bladder and rectum. The dose to the parametria can be increased to 3 erythemas by using the divided dose method through six fields. This is followed by vaginal and intrauterine radium treatment and a second roentgen cycle within six months.

The most important factor in prognosis is the clinical stage of the disease when the disease is begun. The public must be educated to the fact that further improvement in results is dependent on earlier diagnosis.

Dr. O'Brien said in closing that they are using high voltage roentgen treatment before radium when it is possible.—*Audrey G. Morgan.*

Markl, J. Zur Behandlung des Portiokarzinoms. (Treatment of carcinoma of the portio.) *Strahlentherapie*, 1940, *68*, 347–350.

The author reports 57 cases of carcinoma of the portio treated in the first three years of the establishment of his clinic. They are now treating twice as many cases per year. Of these 57 cases only 8 were in the first or second stage. The other 85.9 per cent were in the third or fourth stage. Among the 8 cases of the first and second stages 4 were operated on by the Wertheim method and irradiated afterward. Of these 3 died and 1 was lost track of. The 4 other patients were not operated on because of complications but were treated by radiotherapy alone. Three of these are alive. Among the whole 57 cases 24.5 per cent are cured, after an observation period of from four to six years. This series shows that cancer of the portio can be cured by roentgen treatment alone. With fractional irradiation the dose is 8,000 to 10,000 r. Further increase of the dose does not give any better results.

They are now giving combined roentgen and radium treatment. About half the roentgen treatment is given first; this changes the vaginal flora and decreases the danger of fever and infection on radium treatment. The radium treatment is then given, followed by the second half of the roentgen irradiation.

The radium dose is 6,000 to 8,000 mg-hr. of pure gamma radiation. Special care must be taken to distribute the radium properly so that the whole tumor is irradiated and no injury is

done to the bladder or rectum. If radium is placed in the vault of the vagina it may irritate the rectum and cause mucous diarrhea. As long as there is no blood in the stools the treatment may be continued but as soon as bloody stools appear the treatment must be stopped at once.

In the roentgen irradiation Holfelder's fields are used. In this way the dose is distributed over 9 or 10 fields around the pelvis and there is comparatively little injury of the skin. During the irradiation and for a month afterward the author has the irradiated skin rubbed daily with olive oil and he thinks this decreases the skin reaction. Even with doses of 3,000 r he has seen nothing more than deep brown pigmentation and dry desquamation of the epithelium.—*Audrey G. Morgan.*

KÖRBLER, JURAJ. Zur Radiumtherapie der Rektumkarzinome. (Radium treatment of carcinoma of the rectum.) *Strahlentherapie*, 1940, *68*, 351–356.

The author reports his work in the radium treatment of carcinoma of the rectum at the radium institute of Zagreb, Jugoslavia, from 1931 to 1936. Sixty-four patients were treated, 43 men and 21 women, ranging in age from thirty to seventy-seven. In 30 per cent of the cases the first symptom was painless hemorrhage, without any other symptom; in 8 per cent the bleeding was accompanied by pain on defecation; in 19 per cent the first symptom was gaseous distention of the intestine and in 19 per cent constant constipation from which the patient had not suffered before; in 9 per cent the constipation was accompanied by pain on defecation. In 9 per cent the first symptom was a constant desire to defecate without any result. Diarrhea was the first symptom in only 6 per cent.

Nine of the patients were in such desperate condition on admission that no treatment was given. Three of the patients are still well after seven, seven and eight years. These were a man of sixty-three who had noted the first symptoms of the disease only two months before, a man of thirty-three in whose rectum a wound had been noticed two years before and who had had bloody diarrhea for nine months and a woman of forty-nine who had had symptoms for five months.

Most of the patients were treated by the introduction of radium into the rectum in ametal rubber tubes. In 2 cases the sacral bone was chiselled off and radium needles introduced directly into the tumor. In 10 of the cases combined radium and roentgen treatment was given.

The average length of life in most of these cases was not any longer than in untreated patients. The patients came for treatment on an average eleven to thirteen months after the beginning of symptoms and were to be considered advanced cases. The cases are published rather as a contribution to a detailed knowledge of what happens in such cases for up to the present time the details of radiotherapy have not been worked out carefully enough and sufficient details have not been published to give an idea of what really can be accomplished by this treatment.

From his cases the author believes that the best results are obtained by the introduction of radium into the rectum followed by irradiation from the outside with either radium or roentgen rays.

All operable cases of carcinoma of the rectum should be operated on. As this leaves only severe inoperable cases for radiotherapy not many cures can be reported but for that very reason the cures are of great significance. But in many cases freedom from symptoms can be brought about which is of great value in the patient's life. Therefore in all cases in which operation cannot be performed for any reason radiotherapy is indicated.—*Audrey G. Morgan.*

NEUMANN, WERNER. Über jugendliche Karzinome und ihre Behandlung mit der Chaoulschen Röntgennahbestrahlung. (Carcinoma in young patients and its treatment with Chaoul's contact roentgen irradiation.) *Strahlentherapie*, 1940, *68*, 509–517.

The statistics in regard to the percentage of carcinomata occurring in young people vary from 0.6 to 5.2 per cent, the average being 2 to 4 per cent. The majority of the cases are in females and in the first decade of life they are mostly in the digestive tract, particularly the sigmoid and rectum. After that more carcinomata of the breast and genital tract appear. The statistics quoted are for patients up to thirty years of age.

The results of surgical treatment have been poor. A summary of statistics of these cases shows 50 per cent dead at the end of three years and for carcinomata of the sigmoid and rectum alone the mortality in this time was 85 per cent. Carcinomata in young people have been considered generally more malignant than in older

ones. This may be due partly to the fact that, as the young person's circulation and detoxicating activities are in better condition, no symptoms appear until the cancer is very far advanced.

In the past eight years, since Chaoul's method of contact roentgen irradiation has been in use the author has treated 750 carcinoma patients, 17 of them between eighteen and thirty years of age. Of these 11 were female and 6 male. The site was in the rectum in 3 females and 0 males, the skin in 2 females and 2 males, the larynx in 1 female and 1 male, the breast in 2 females and 1 male, the parotid gland in 2 females and 1 male and there were 2 cases of melanoma, 1 in a female and 1 in a male. Half of the cases were inoperable.

Among these 17 patients 10, or 59 per cent, are alive after from one to seven and a half years. Counting the two melanoma patients, who died of intercurrent disease and in whom autopsy showed no signs of recurrence or metastasis, the percentage rises to 70.

This group of cases shows that the Chaoul method of irradiation at a short distance is much superior to surgery in the treatment of carcinoma in young people. Reference is made to Chaoul's work for the details of the technique. Surgery seems to tend to disseminate the carcinoma instead of cure it while the youth of the patients provides optimum conditions for the elimination of products of catabolism of the tumors and for healing in the irradiated area.—*Audrey G. Morgan.*

Voss, Friedrich. Über Wirkung und Dosierung der Paralysebehandlung mit Röntgenstrahlen. (The action and dosage of roentgen rays in the treatment of paralysis.) *Strahlentherapie*, 1940, *68*, 498–508.

The author reports his experience in the treatment of progressive paralysis by roentgen irradiation. He at first followed Bering's dosage but found the loss of hair so troublesome that he reduced the dosage. However, he found that the larger dosage was more effective. At present he irradiates over five to six fields 10×15 cm. in size, the forehead, vertex, biparietal and occipital fields and sometimes a suboccipital field. In the course of two weeks or sometimes less 200 to 320 per cent skin erythema dose is given, equivalent to 1,200 to 1,920 r with a half-value layer of 1 mm. copper. The apparatus used (Siemens-Tuto-Stabilivolt) with a tension of 180 kv. and 4.9 ma., with a focus-skin distance of 30 cm. and a filter of 0.5 mm. copper yields about 50 r/min. at the tube, field 10×15 cm., measured with a finger-cot chamber embedded in paraffin.

In cases with a rapid course and a high lymphocytosis in the spinal fluid care must be used in dosage, the total dosage being lowered or the irradiations protracted over a longer time. The latter can be done if it is possible to repeat the irradiation after some months. The first irradiation should be given as a test dose in order to avoid a possible mistaken diagnosis of brain tumor.

In many patients after the first irradiations signs appear of the action of the rays on certain parts of the brain. Among these signs are disappearance of the headache and improvement in attention and memory. The disinclination for physical or mental effort is changed into intense activity. The patients say that "their minds seem to be so clear" that they can concentrate and want to go back to work. There is generally an increase of weight which may reach 6 to 10 kg. in the first few weeks. There is a marked improvement in the psychic condition.

On the basis of measurements of the superficial and deep dose with the Siemens Universal dosimeter the author discusses the mechanism of action of the rays on the brain, but without arriving at any very definite conclusions.—*Audrey G. Morgan.*

Csonth, László, and Horváth, Zoltán. Unsere Erfolge in der Gynäkologie mit der Chaoulschen Nahbestrahlung. (Our results in gynecology with Chaoul's contact irradiation.) *Strahlentherapie*, 1940, *68*, 277–286.

The authors report their results in 63 gynecological cases treated with Chaoul's contact irradiation. They included 43 patients with cancer of the uterus, 3 with cancer of the body of the uterus, 3 with cancer of the vulva, 1 of recurrent epithelioma of the vault of the vagina, 1 with a malignant tumor of the vaginal connective tissue, 1 with leukoplakia of the vulva, 7 with erosions of the os, 3 with hemorrhagic endometritis and 1 with bilateral tumors of the adnexa.

Technique: 60 kv., 4 ma., 0.2 mm. copper filter, 3 to 5 cm. focus-skin distance, 400 r, measured in air, daily, total dose 4,000 to 8,000 r. With very large tumors the direction of the rays was changed each day so as to cover all the tumor. If the desired results were not attained the treatment was repeated after four to six

weeks. The tumors were removed by excision and electrocautery before the treatment.

None of these cases are recorded as cured as none of them was treated as long as five years ago. But 14 of the carcinoma patients are free of symptoms, 16 improved and 20 have been lost sight of, grown worse or died. The authors find that this close irradiation with soft rays has particularly good results in tumors that lie on or near the surface. In deeper tumors the results are not so good and the method is not recommended for tumors of the body of the uterus. It gives excellent results in cancer of the cervix of the first and second degree and even in cases of the third and fourth degree the condition of the patients may be improved and life lengthened. They think that the total dose should be at least 8,000 r. The method is recommended particularly for hospitals that do not have any radium available.

It is well to give the irradiation before operation as it does not cause contraction and cicatrization of the tissues and by bringing about healing of the ulcers decreases the danger of infection. It does not injure the bladder or rectum.

They are convinced that with improvement in the technique the results will be still further improved.—*Audrey G. Morgan.*

NAKAIDZUMI, M., and MIYAKAWA, T. Zur Rotationsbestrahlung mit Hilfe einer ständingen Durchleuchtungskontrolle für den Osophaguskrebs. (Rotation irradiation of cancer of the esophagus under constant screen control.) *Strahlentherapie*, 1940, *68*, 254–262.

It has been found that with rotation irradiation a pathological focus at a depth of 10 cm. can be given a dose two or three times the skin dose. The method has proved particularly valuable in the treatment of cancers of the esophagus, rectum, nasopharynx and hypophysis. Among the 44 cases of stenosis of the esophagus from cancer which the authors have treated during the year 1938 this method was used in 36. There was improvement in 32 of these with regard to the stenosis, the subjective symptoms and the general condition. Of course it is impossible to give final results as yet as this method was introduced in the treatment of cancer of the esophagus in the beginning of 1938.

Their patients were seated in a dark deep therapy room on a chair which rotated once in sixty minutes. They swallowed a lead shot, or if unable to do that, some barium paste, and were kept under a fluorescent screen so that the tumor always lay in the cone of rays. The tension was 160 kv. and the filter 0.25 mm. copper. This may be rather thin but they wanted to give as intense a dose in as short a time as possible. About 500 r was given daily and the total dose was 3,000 to 12,000 r in ten to thirty days.

The advantage of this method is that a large deep dose can be given without injuring the skin or seriously affecting the general condition. In 3 of the authors' cases the treatment had to be given up but all of these patients had extreme stenosis and were in very serious general condition.—*Audrey G. Morgan.*

HAWLEY, S. J. Rotation therapy. *Radiology*, July, 1940, *35*, 65–69.

In rotation therapy of deep lesions the patient is rotated continuously in the beam with the central ray directed horizontally through the center of the part to be treated. This may be done by rotating the tube around the patient or the patient around the tube, preferably the latter. A diagram is given of the arrangement of the tube and patient. The advantage of the method lies in the fact that when the patient is rotated in the beam there is a cylinder of tissue surrounding the axis of the beam which is in the beam continuously during the irradiation. All tissue outside this cylinder is irradiated only as it passes through the beam anterior and posterior to the center of rotation. Therefore the irradiation of the skin and superficial tissues is slight as compared with the dosage given to the deep tissues within the irradiated cylinder. Curves are given showing the distribution of the radiation in the body and the deep and surface doses for cross-sections of various sizes and for various sizes of fields with different qualities of radiation.

The advantageous ratio between deep and surface doses is greater with large bodies, small fields and short wave length. With large fields such as are required for large tumors in small patients part of the advantageous ratio of surface-to-depth dose is lost but the advantage of more certain and uniform distribution of radiation within the body as compared with multiple stationary fields is maintained.—*Audrey G. Morgan.*